

# **NORTHERN TERRITORY NATURALIST**

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**Front Cover:** Regular sightings of the False Killer Whale *Pseudorca crassidens* in shallow enclosed bays along the NT coast are unexpected. (Peter Fitzgerald)

**Back Cover:** Larvae of the Scarlet Jezebel *Delias argenthona*, an obligate mistletoe-feeding butterfly species. (Michael Braby)

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## Invertebrate diversity associated with tropical mistletoe in a suburban landscape from northern Australia

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### Abstract

The invertebrate fauna associated with the tropical mistletoe *Decasynina signata* (Loranthaceae) parasitising a range of host trees was surveyed during the late dry-season (September-October) in suburban areas of Darwin, Northern Territory, a landscape which comprises extensive patches of natural vegetation within the urban matrix. A total of 113 species of insects and spiders representing 51 families and 12 orders was recovered from 38 samples. The estimated total species richness, however, suggests another 116 species are likely to occur on the mistletoe according to the incidence-based coverage estimator (ICE). Hymenoptera (especially Formicidae), Hemiptera (particularly Miridae), Araneae and Lepidoptera were the most dominant groups in our samples in terms of both species richness and relative abundance (measured as % site occupancy). Thysanoptera, Coleoptera and Psocoptera were also comparatively diverse but were substantially less abundant. Overall species and family richness were both positively correlated with mistletoe biomass, but the composition and taxonomic richness of invertebrates associated with mistletoes parasitising different host genera (*Planchonia* vs. *Alstonia*) or host species (*Alstonia scholaris* vs. *A. actinophylla*) were not significantly different. Our findings are in broad agreement with limited previous studies elsewhere that indicate mistletoes support a wide range of invertebrates, some of which are obligate specialists. We hypothesize that mistletoes support a unique assemblage of invertebrates that is independent of the host tree.

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## Introduction

Mistletoes are a functional group of aerial-stem hemiparasitic plants in the plant order Santalales. Most mistletoes selectively parasitise trees and shrubs in forests and woodlands (Calder & Bernhardt 1983) and it has been demonstrated that the arboreal parasitic habit has arisen independently five times, in the families Misodendraceae, Loranthaceae, Santalaceae, 'Santalaceae' (Amphorogyneae) and Viscaceae (Vidal-Russell & Nickrent 2008). Watson (2001) concluded that mistletoes represent a critical keystone resource in these habitats worldwide because they support high biodiversity and facilitate numerous complex ecological interactions, including pollination, frugivory and herbivory. Mistletoes have also been found to increase ground litter mass and plant productivity, measured in terms of understorey plant biomass (March & Watson 2007).

Although birds and to some extent mammals use mistletoes as a resource for food and breeding sites (Reid 1987; Watson 2001; Cooney *et al.* 2006), there has been comparatively little research on insect communities associated with mistletoes worldwide. Perusal of the literature indicates that, at the species level, insects regularly feed on mistletoes, including the nectar of flowers (Barlow 1966; Stevens & Hawksworth 1970; Bernhardt & Calder 1981; Nickrent 1988), the woody tissue of the haustorium, stems or dead branches (Miller & Keen 1960; Room 1972a; Hawksworth & Peterson 1982; Whittaker 1984; De Baar 1985a,b; Williams 1985; McMillan 1987; Common 1990), and the leaves, non-woody stems, fruits or flowers (Watt & Casimir 1962; Stevens & Hawksworth 1970; Room 1972a; Whittaker 1984; Scharpf & Koerber 1986; De Baar 1985a,b; Common 1990; van Harten 1996; Patrick & Dugdale 1997; Taylor 1999; Braby 2000, 2005, 2006; Lane & Edwards 2005; Braby & Nishida 2007). In addition, they may serve as effective pollinators of mistletoes (Barlow 1966; Stevens & Hawksworth 1970; Penfield *et al.* 1976; Bernhardt & Calder 1981; Kelly *et al.* 1996; Ladley *et al.* 1997; Nickrent 1988; Robertson *et al.* 2005). Moreover, several observations suggest complex interactions amongst the various insect feeding guilds. For example, Room (1972b) noted that wood borers (Coleoptera and Lepidoptera) provide holes for mealy bugs (Homoptera), which are attended by large numbers of ants (Hymenoptera) to obtain honeydew; the ants in turn appear to provide protection to the mistletoe by reducing attack from insect herbivores. In Australia, wood-boring beetles such as the weevil *Metyrus albicollis* Germ. (Coleoptera) create tunnels inside the haustorium and woody branches of mature clumps of *Anyema* (De Baar 1985a,b; McMillan 1987); ants of the genus *Froggattella*, *Crematogaster* and others such as *Tetraponera* frequently establish nests inside the tunnels, which are also used as convenient shelters by larvae of some species of *Ogyris* (Lepidoptera) which have an obligate relationship with the ants (Eastwood & Fraser 1999).

Interestingly, while there are numerous examples in the literature of insects feeding obligatorily on mistletoes, there are relatively few cases of lineages radiating adaptively on mistletoes. For example, in the Lepidoptera only four instances of adaptive



radiation are known: in the subtribe Aporiina (Pieridae) from Africa, Asia-Australia and South America (Braby 2005, 2006; Braby & Trueman 2006; Braby *et al.* 2007; Braby & Nishida unpubl.); in the *Hesperocharis* group of the tribe Anthocharidini (Pieridae) from Central and South America (Braby & Nishida 2007); in the tribe Iolaini (Lycaenidae) from Africa (Congdon & Bampton 2000); and in the tribe Ogyrini (Lycaenidae) from Australia (Braby 2000).

While there is clearly an extensive literature documenting insects and other invertebrates associated with mistletoes, there are remarkably few studies that describe the invertebrate assemblage as a whole and the spatial and/or temporal patterns of these communities for particular mistletoe taxa. A detailed review of *Arctanthobium* (Viscaceae) in the western USA and Mexico indicated a rich and varied arthropod fauna associated with the genus (Stevens & Hawksworth 1970). Room (1972a) undertook a comprehensive survey of the invertebrate fauna associated with *Tapinanthus bangwensis* (Engl. & K.Krause) Danser (Loranthaceae) from Ghana in tropical West Africa and recorded over 610 species from the branches and leaves, and more than 440 species from the haustorium and hypertrophied host tissue, representing 18 orders from the Crustacea, Insecta, Arachnida and Mollusca. In terms of species richness, the most dominant orders sampled were Araneae, Hymenoptera, Coleoptera, Lepidoptera and Hemiptera. Whittaker (1984) provided a detailed inventory of the temperate insect fauna on *Phoradendron tomentosum* Engelm. ex A.Gray (Viscaceae) from southern Texas, USA; between spring and mid autumn 43 species of insects were recorded, of which the Hymenoptera, Hemiptera, Coleoptera and Lepidoptera were the most diverse.

The aim of this study is to describe the spider and insect assemblage associated with the tropical mistletoe *Decaismia signata* (F.Muell. ex Benth.) Tiegh. (Loranthaceae) within a suburban landscape during the late dry-season, as part of a broader survey to document the invertebrate diversity of mistletoes in northern Australia. In addition, we compare the composition and taxonomic richness of invertebrates recorded on *D. signata* parasitising two distantly related host tree genera (*Planchonia* vs. *Alstonia*) and two closely related host tree species (*Alstonia scholaris* vs. *A. actinophylla*) to establish if host tree affects diversity. If it is assumed that mistletoe invertebrate diversity is dependent on the host tree, then our prediction is that the mistletoe-invertebrate fauna will be different among host tree categories because the hosts are distantly related taxonomically and therefore likely to support different faunas that colonise or interact with mistletoes. Moreover, *Alstonia* (Apocynaceae) has milky white sap containing alkaloids and other toxic compounds (e.g. Arulmozhi *et al.* 2007; Oigiangbe *et al.* 2007), which are known to deter insect herbivores and sap-suckers, so one might predict that such host trees harbour a more specialised fauna that colonises mistletoes compared with that associated with *Planchonia* (Lecythidaceae), which does not contain these compounds.

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## Methods

### *Study species*

*Decaisnina* includes six species in the monsoon tropics of northern Australia, of which four occur in the Northern Territory (NT). *Decaisnina signata* (Figure 1) is endemic to the Kimberley, WA, and the Top End of the NT (Barlow 1993), and is the predominant species of the genus in the Darwin region (Dunlop *et al.* 1995). It has spectacular, showy red flowers and occurs in both monsoon forests and savanna woodlands (Barlow 1993). It is well established in suburban areas of Darwin (Figure 1) where its main hosts are species of *Planchonia*, *Alstonia*, *Eucalyptus*, *Melaleuca* and *Syzygium* (Clark & Traynor 1987; Barlow (1993) and Downey (1998) listed several other native genera on which it grows. *Decaisnina signata* is the most abundant mistletoe within Darwin, in part due to its ability to parasitise a wide range of both native and ornamental host trees. It is known to serve as a larval food plant for the butterfly (Lepidoptera) Scarlet Jezebel *Delias argentifrons* (Fabricius) (Wade 1978), Northern Pencil-blue *Candalides margarita gilberti* Waterhouse (Samson & Wilson 1995) and Northern Purple Azure *Ogyris zosine* (Hewitson) (Braby 2000). For these reasons, *D. signata* was chosen as our preferred study species.

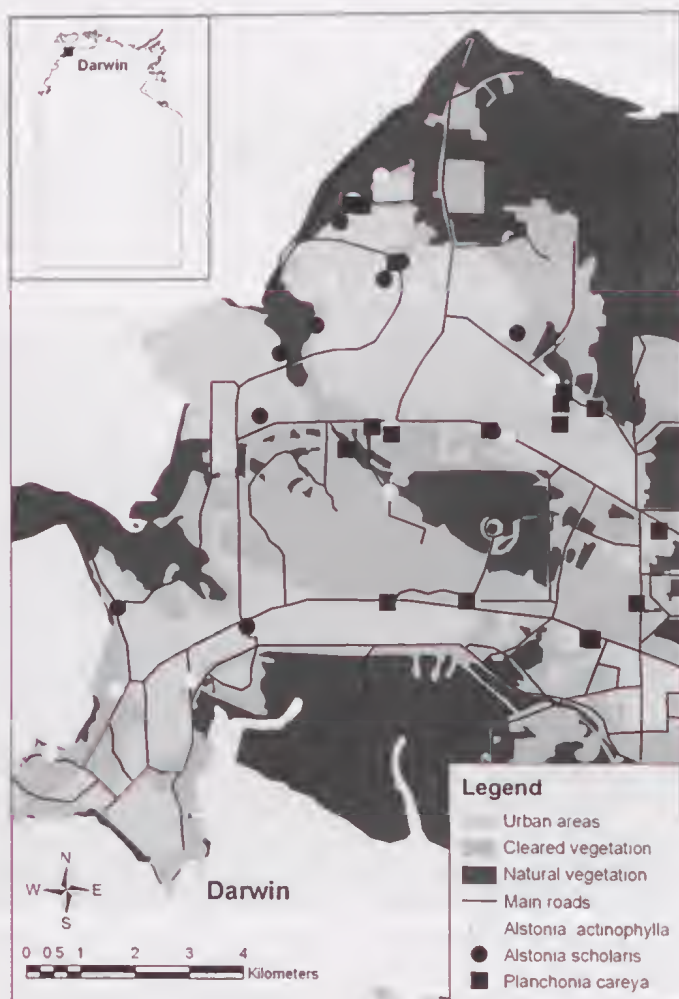


**Figure 1.** (A) Suburban habitat in Darwin, NT, showing the ornamental host tree *Alstonia scholaris* supporting clumps of the study mistletoe *Decaisnina signata*; (B) habitus of *D. signata* parasitising *A. scholaris* (inset photo shows inflorescence of *D. signata*).

### Study area and host trees

In order to describe the invertebrate fauna associated with *Decaishnia signata*, 38 sites (i.e. mistletoe clumps) were selected throughout the suburbs of Darwin, NT (Figure 2). All sites were located either in urban areas (usually on road nature strips or near footpaths), or in suburban parklands associated with cleared or disturbed vegetation. No sites were located in areas comprising natural vegetation, although several were close to small patches of natural habitat.

**Figure 2.** Map of study area showing sampling sites in the Darwin district (inset map shows Northern Territory and location of Darwin). Host trees for each site are indicated in the legend.





To test for host tree effects on invertebrate diversity, mistletoe clumps parasitising two distantly related host genera were sampled: Cocky Apple *Planchonia careya* (F.Muell.) R.Knuth (Leechthidaceae) (18 sites) and *Alstonia* (Apocynaceae) (20 sites). Within the *Alstonia* host trees, two species were compared: Cheesewood or Milky Bean *A. scholaris* (L.) R.Br. and Milkwood *A. actinophylla* (A.Cunn.) K.Schum., with ten mistletoe sites sampled for each. *Planchonia careya* naturally occurs widely across the monsoon tropics of northern Australia and is a common understorey tree growing 4-10 m high in open-forest and woodland. It is semi-deciduous or deciduous during the mid dry-season (July-August) when trees frequently shed most or all of their leaves. Of the two species of *Alstonia* in the Darwin region, only *A. actinophylla* is indigenous; it occurs naturally in open-forest and woodland, but also in monsoon forest (semi-deciduous coastal monsoon vine-thicket, monsoon vine-forest), where it grows as a large evergreen tree 15-20 m high with a spreading crown and thick short trunk. *Alstonia scholaris* was introduced to the Darwin region as an ornamental street tree (Figure 1); it occurs naturally in Queensland where it grows as an emergent tree (>10 m) in rainforest. All three host trees are readily parasitised by *D. signata*, and on some trees, especially plants growing in more exposed situations or the non-indigenous species *A. scholaris*, infestations may reach exceedingly high levels.

### Sampling

Invertebrates were sampled during the late dry-season (September-October 2006) between 0600-1100 h (i.e. during calm, dry, sunny weather). The number of mistletoe clumps on each host tree was recorded. Where two or more mistletoe clumps occurred on a host tree, only one clump was sampled, generally that which was accessible by foot or ladder. Mistletoe clumps touching the ground or those near the canopy of the host tree were not sampled to avoid possible loss of invertebrates during sampling. Because of the potential negative impact of Green Tree-ants *Oecophylla smaragdina* (Fabricius) (Hymenoptera: Formicidae) on invertebrate diversity, clumps with colonies of this predaceous ant species were avoided.

Clumps of mistletoes were enclosed in 75 L plastic bags, removed from the host tree at their point of attachment, weighed, and then transferred to a freezer (-10°C). After 24 h, invertebrates were removed from each sample as follows. Branches were broken into approximately 250 mm lengths, placed in a 5 L container and submerged in 150 mm of water. Leaves, flowers, fruits, buds and stems were inspected visually for invertebrates, with the woody parts broken into 50 mm lengths to isolate borers. The collection bag was then submerged in a separate container of water to remove additional invertebrates. Contents of both containers were filtered through a 0.025 mm polyester sieve; after filtering, invertebrates were flushed with 70% ethyl alcohol. All invertebrates were removed, sorted and preserved in vials with 70% ethyl alcohol.

The destructive sampling method was found preferable over other methods. An alternative method of enclosing the mistletoe clump inside a large plastic bag and spraying with pyrethrum-based insecticide and shaking the foliage to dislodge invertebrates (A. Burns, pers. comm.), was not suitable as it caused larvae and other small insects to adhere to the leaves and stems. Difficulty was experienced in identifying Lepidoptera larvae to family level regardless of the sampling method adopted. To overcome this, samples of larvae (where sufficient duplicates were available) were kept alive and reared to adulthood in small plastic containers (160 mm x 110 mm x 80 mm) supplied with fresh cuttings of leaves and/or flowers.

Invertebrates (spiders and insects) were identified to the level of order and family. With the exception of thrips (Thysanoptera), moths and butterflies (Lepidoptera) and ants (Hymenoptera: Formicidae), lower taxa were not identified to species level, but were distinguished on the basis of clear morphological differences (i.e. morphospecies). The following works were consulted to assist with routine identifications: CSIRO (1991), Rentz (1996), Andersen (2000), Braby (2000), Brunet (2000), Cassis *et al.* (2002), Lawrence *et al.* (2000), Raven *et al.* (2002), Zborowski and Storey (2003), Horne and Crawford (2005) and Grimaldi and Engel (2005).

### Statistical analyses

Species accumulation curves and species richness were estimated using Version 8.0.0 of the EstimateS software program (Colwell 2006). The program computes the expected species richness (Mao Tau) for a given set of samples, as well as the incidence-based coverage estimate (ICE), to determine total species richness.

To detect patterns of similarity in species composition of invertebrates among mistletoe clumps growing on different host trees (three levels), multivariate analysis employing an ordination method based on semi-strong hybrid multidimensional scaling (SSH MDS) was implemented using PATN v3.03. Bray-Curtis similarity measure was applied to the data set (species by sites) to create a symmetric diagonal matrix of similarities, analogous to correlation coefficients ranging from 0 (indicating that sites are different, with no species in common) to 1 (sites are similar, with all species in common) with a cut-off point of 0.01. The approach of using presence/absence data was preferred over using abundance data because of the high proportion of singletons and the fact that abundances varied greatly between life stages within species (e.g. larvae/nymphs were more abundant than adults). The three host tree levels tested were *Planchonia careya*, *Alstonia scholaris* and *A. actinophylla*.

Taxonomic richness was analyzed at two levels, species and family, using Stata v8.2. Parametric methods were used because species and family richness across sites were both found to be normally distributed (Shapiro-Wilk W test). Initial inspection of the data revealed that taxonomic richness was positively related to plant biomass (i.e. fresh weight) so mistletoe weight was included to control for biomass. Therefore, to test for possible differences among invertebrates on mistletoe clumps growing on

different host trees, taxonomic richness (dependent variable) was analysed using one-way analysis of covariance (ANCOVA), with MISTLETOE WEIGHT as the covariate. For each level of taxonomic richness, two analyses were performed on the independent variable host tree, each with two categories. First, host tree was analysed at the generic level HOST TREE GENERA, with the two categories being *Planchonia* and *Alstonia*. Second, within *Alstonia*, host tree was analysed at the specific level HOST TREE SPECIES, with two categories: *A. scholaris* and *A. actinophylla*. Because of the small sample sizes (only 10 samples for each category of HOST TREE SPECIES treatment were tested), a stringent standard for testing of significance ( $P < 0.01$ ) was adopted, thereby minimising the risk of type I errors.

## Results

### Composition

Table 1 provides a summary of the higher taxonomic groups at the ordinal and familial levels, number of morphospecies and relative abundance, given as the percentage site occupancy or frequency of occurrence across sites. A more detailed list summarising the species by site data for each sample is given in the Appendix. In total, 113 species of invertebrates representing 12 orders and 51 families were recorded on *Decaishnina signata*. An additional nine species from five orders were recorded but could not be accurately identified to family level. Hymenoptera (29 species, 11 families), Hemiptera (16 species, 8 families), Coleoptera (11 species, 5 families), Araneae (11 species, 3 families), Thysanoptera (11 species, 2 families), Lepidoptera (9 species, 6 families) and Psocoptera (9 species, 5 families) were relatively diverse in terms of taxonomic richness at the species level, whereas Neuroptera (3 species, 3 families), Collembola (1 species) and Mantodea (1 species) were relatively poor at both taxonomic levels (Table 1). The remaining two orders (Diptera, Blattodea) were, by comparison, moderately represented with seven and five species, respectively. In terms of relative abundance, the most frequently sampled taxa across sites were Araneae (97%), Hemiptera (92%), Hymenoptera (87%) and Lepidoptera (71%). Although Thysanoptera, Coleoptera and Psocoptera were relatively species rich, they were not abundant numerically (47%, 45%, 32% respectively). In contrast, Blattodea were relatively abundant (66%) but substantially less diverse. Diptera (16%), Neuroptera (13%), Collembola (3%) and Mantodea (3%) were sampled very infrequently. Hence, in terms of both species richness and relative abundance the most dominant groups in our samples were Hymenoptera (especially Formicidae), Hemiptera (particularly Miridae), Araneae and Lepidoptera (Table 1).

Plots of the cumulative number of species against the number of sites sampled give an indication of sampling effectiveness and whether all invertebrates were surveyed. Figure 3a shows that the accumulation curves were still increasing after 38 samples (all sites pooled), with no clear sign of reaching an asymptote. This trend is seen more

clearly with ICE estimator in which the trajectory of the curve has not levelled off after the 38 samples, with a minimum mean estimated total species richness of 229 (Figure 3b). These estimates strongly indicate that the late dry-season invertebrate fauna was not fully surveyed, and that our overall sample represented about 49% of the total fauna. Despite these limitations, ordination of sites according to host tree genera and host species showed no clear separation of the data (Figure 4), indicating that the invertebrate composition was not significantly different among the host treatments.

**Table 1.** Taxonomic composition of invertebrates recorded at the ordinal and familial level on *Dectasmina signata*. For each taxonomic level, the number of morphospecies and relative abundance (% sites occupied,  $n = 38$ ) are also given. See Appendix for further details.

Order	Family	No. of species	% sites occupied
Araneae	Salticidae	7	50.0
	Tetragnathidae	2	7.9
	Heteropodidae	1	2.6
	Unplaced	1	97.4
	<b>Total</b>	<b>11</b>	<b>97.4</b>
Collembola	Entomobryidae	1	2.6
Blattodea	Blattellidae	5	65.8
Mantodea	Mantidae	1	2.6
Psocoptera	Pachytroctidae	1	2.6
	Caeciliidae	1	5.3
	Ectopsocidae	2	10.5
	Archipsocidae	1	2.6
	Philotarsidae	1	2.6
	Unplaced	3	26.3
	<b>Total</b>	<b>9</b>	<b>31.6</b>
Thysanoptera	Thripidae	4	15.8
	Phlaeothripidae	7	47.4
	<b>Total</b>	<b>11</b>	<b>47.4</b>
Hemiptera	Aphididae	1	10.5
	Pseudococcidae	1	13.2
	Cicadellidae	2	31.6
	Tropiduchidae	1	15.8
	Flatidae	3	7.9
	Miridae	6	81.6
	Tingidae	1	2.6
	Pentatomidae	1	7.9
	<b>Total</b>	<b>16</b>	<b>92.1</b>
Diptera	Culicidae	1	2.6
	Ceratopogonidae	3	7.9
	Cecidomyiidae	1	2.6
	Sciaridae	1	2.6
	Sphaeroceridae	1	2.6
	<b>Total</b>	<b>7</b>	<b>15.8</b>

Table 1 continued

Order	Family	No. of species	% sites occupied
Coleoptera	Curculionidae	3	7.9
	Scolytidae	1	5.3
	Silvanidae	1	5.3
	Phalacridae	1	5.3
	Coccinellidae	2	15.8
	Unplaced	3	10.5
	<b>Total</b>	<b>11</b>	<b>44.7</b>
Neuroptera	Mantispidae	1	2.6
	Hemerobiidae	1	2.6
	Chrysopidae	1	7.9
	<b>Total</b>	<b>3</b>	<b>13.2</b>
Lepidoptera	Psychidae	2	5.3
	Immidae	1	13.2
	Pyalidae	1	28.9
	Geometridae	1	2.6
	Pieridae	1	2.6
	Lycaenidae	2	5.3
	Unplaced	1	31.6
	<b>Total</b>	<b>9</b>	<b>71.1</b>
Hymenoptera	Formicidae	11	68.4
	Chalcididae	1	2.6
	Pteromalidae	1	7.9
	Encyrtidae	4	13.2
	Agaonidae	1	7.9
	Scelionidae	4	34.2
	Aphelinidae	1	13.2
	Braconidae	2	10.5
	Bethylidae	1	2.6
	Eulophidae	1	2.6
	Elasmidae	1	2.6
	Unplaced	1	7.9
	<b>Total</b>	<b>29</b>	<b>86.8</b>

### Taxonomic richness

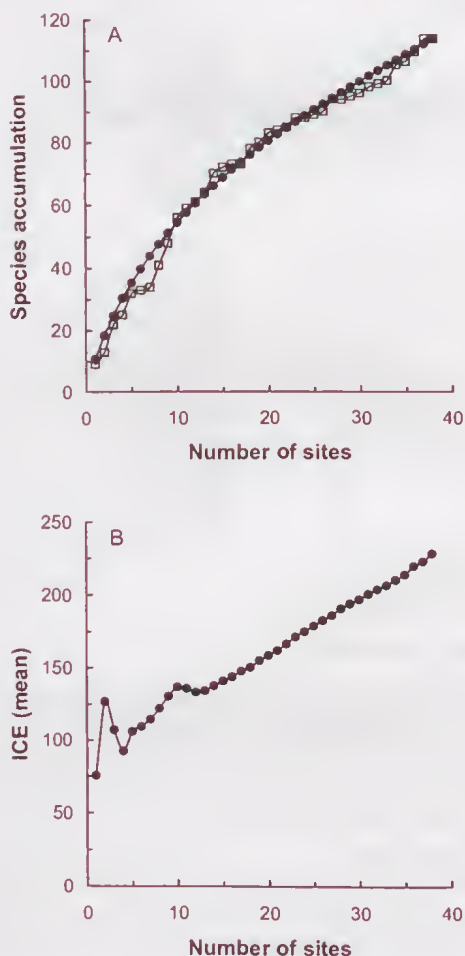
The frequency distribution of species richness (Figure 5a) and family richness (Figure 5b) across sites indicated that the number of invertebrate species sampled per site varied from 3 to 17 ( $\bar{x} = 10.3 \pm 3.85$  s.d.), while the number of families sampled varied from 2 to 12 ( $\bar{x} = 6.8 \pm 2.63$  s.d.). Variation in taxonomic richness was found to be unrelated to the number of mistletoe clumps on host trees for both invertebrate species and families ( $r = 0.09$ , d.f. = 36,  $P > 0.10$ ), but was positively correlated with mistletoe biomass (Figure 6). There was a highly significant linear relationship between mistletoe fresh weight and richness of both species ( $F = 16.30$ , d.f. = 36,  $P = 0.0003$ ) and families ( $F = 11.68$ , d.f. = 36,  $P = 0.0016$ ).

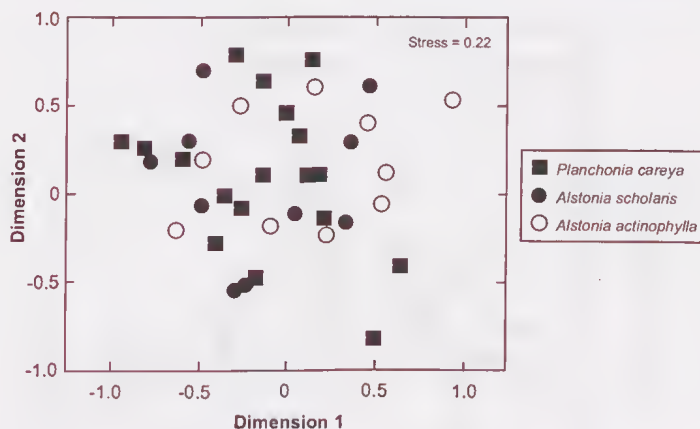


Mistletoe host tree had no effect on taxonomic richness, with similar numbers of invertebrate species (Figure 7a) and families (Figure 7b) recorded among the host tree categories. One-way ANCOVA, with MISTLETOE WEIGHT as the covariate, revealed no significant difference between invertebrate species richness on the HOST TREE GENERA *Planchonia* ( $\bar{x} = 9.2 \pm 1.06$  s.e.) and *Alstonia* ( $\bar{x} = 11.0 \pm 0.80$  s.e.) or between the HOST TREE SPECIES *Alstonia scholaris* ( $\bar{x} = 10.5 \pm 1.49$  s.e.) and *A. actinophylla* ( $\bar{x} = 11.5 \pm 0.69$  s.e.) at the  $P < 0.01$  level (Table 2). Similarly, there was no significant difference in invertebrate family richness between *Planchonia* ( $\bar{x} = 5.5 \pm 0.62$  s.e.) and *Alstonia* ( $\bar{x} = 7.2 \pm 0.60$  s.e.), or between *Alstonia scholaris* ( $\bar{x} = 7.3 \pm 1.07$  s.e.) and *A. actinophylla* ( $\bar{x} = 7.0 \pm 0.60$  s.e.) (Table 3).

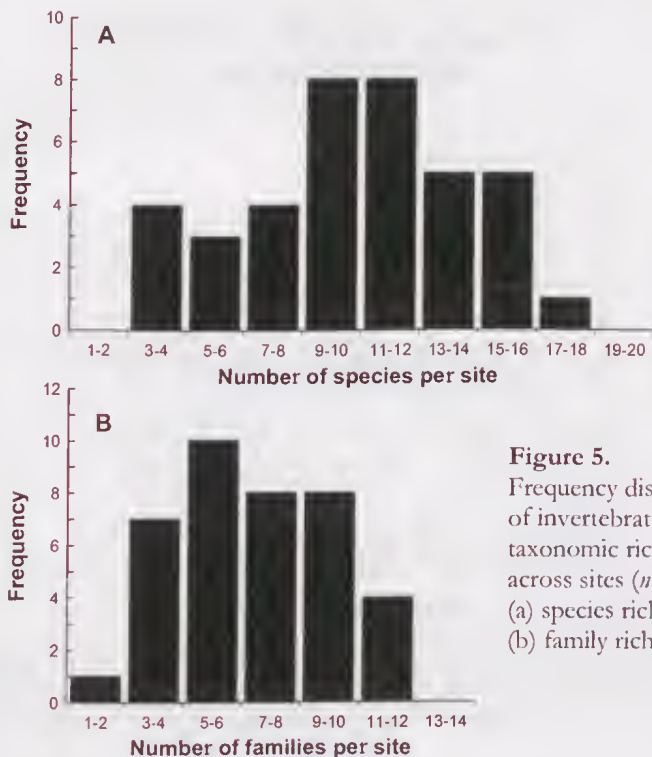
**Figure 3.**

Species accumulation curves and total predicted species richness curve based on incidence-based coverage estimator in relation to the number of mistletoes sampled (all sites pooled): (a) actual cumulative number of species ( $\square$ ) and modeled species accumulation (Mao Tau) ( $\bullet$ ); (b) cumulative incidence-based coverage estimate (ICE).

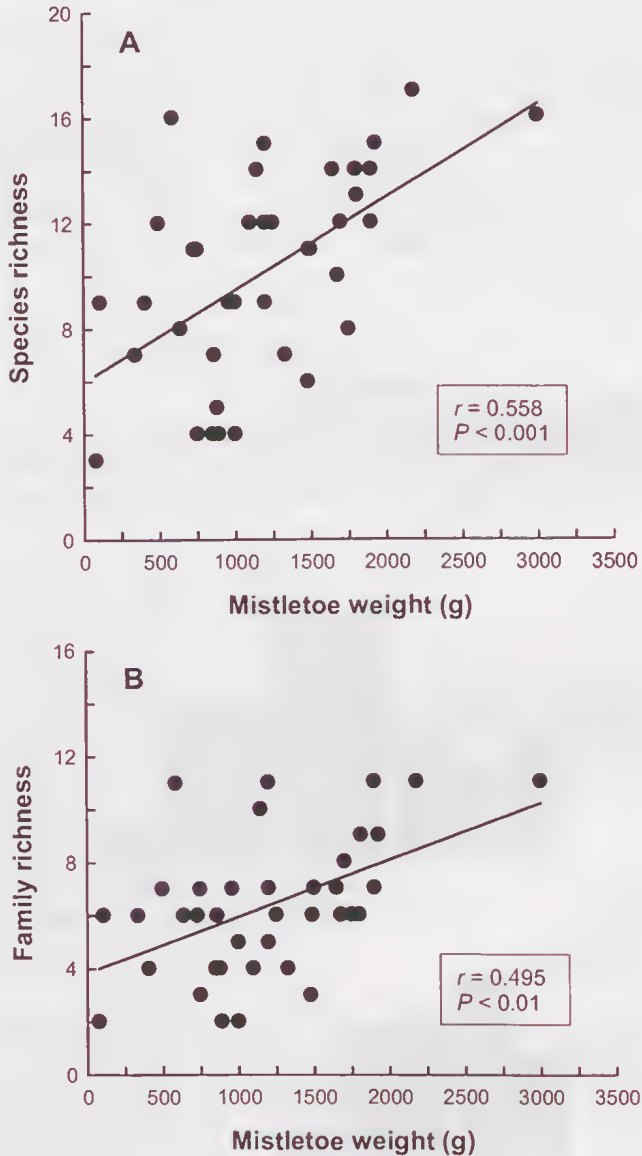




**Figure 4.** Multidimensional scaling ordination plot showing invertebrate composition associated with mistletoes parasitising three different host trees. Points represent Bray-Curtis similarity values based on presence-absence data (see Appendix for data).



**Figure 5.** Frequency distribution of invertebrate taxonomic richness across sites ( $n = 38$ ): (a) species richness; (b) family richness.



**Figure 6.** Relationship between invertebrate taxonomic richness and mistletoe fresh weight (all sites pooled): (a) species; (b) families. Regression equations:  $y = 0.0035x + 5.97$  ( $r^2 = 0.31$ ,  $n = 38$ ) for species richness;  $y = 0.0021x + 3.84$  ( $r^2 = 0.24$ ,  $n = 38$ ) for family richness.

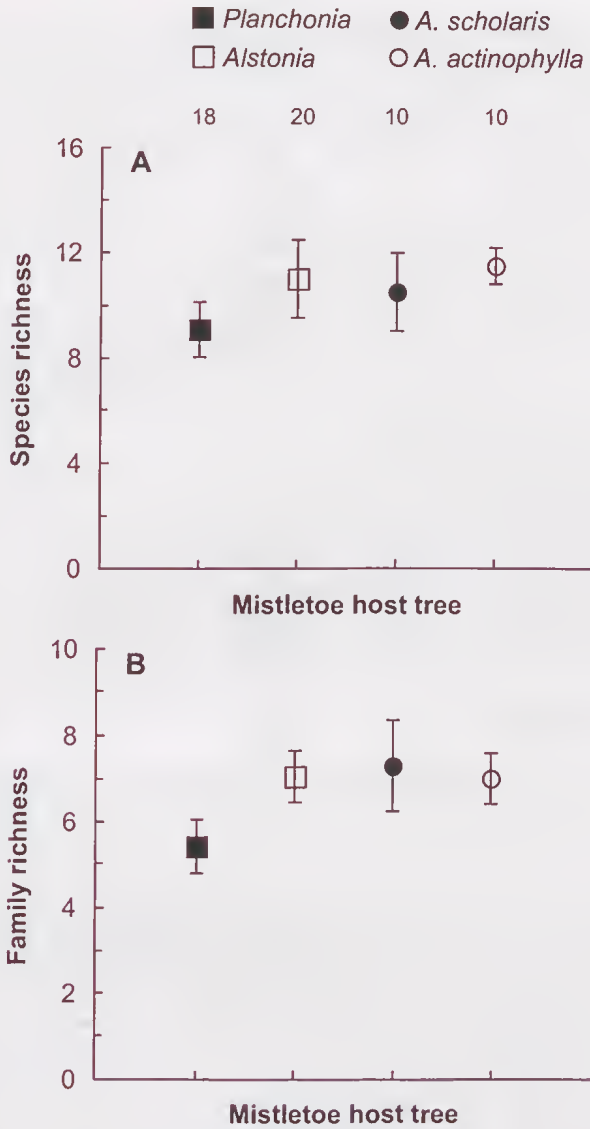


Figure 7. Invertebrate taxonomic richness (mean  $\pm$  s.e.) recorded on mistletoe clumps parasitising different host tree genera (*Planchonia*, *Alstonia*), and different host tree species (*Alstonia scholaris*, *A. actinophylla*): (a) species richness; (b) family richness. Sample sizes are given above data points.

Table 2. One-way analyses of covariance of host tree genera (*Planchonia*, *Alstonia*) and host tree species (*Alstonia scholaris*, *A. actinophylla*) on invertebrate species richness, with mistletoe weight as covariate.

Source of variation	d.f.	MS	F	P
HOST TREE GENERA	1	13.6434	1.57	0.2183
MISTLETOE WEIGHT	1	98.1904	11.32	0.0019
Error	35	8.6727		
HOST TREE SPECIES	1	30.5274	4.79	0.0437
MISTLETOE WEIGHT	1	55.6251	8.73	0.0093
Error	17	6.3687		

Table 3. One-way analyses of covariance of host tree genera (*Planchonia*, *Alstonia*) and host tree species (*Alstonia scholaris*, *A. actinophylla*) on invertebrate family richness, with mistletoe weight as covariate.

Source of variation	d.f.	MS	F	P
HOST TREE GENERA	1	13.8706	3.46	0.0715
MISTLETOE WEIGHT	1	31.4828	7.86	0.0083
Error	35	4.0073		
HOST TREE SPECIES	1	2.3407	0.51	0.4871
MISTLETOE WEIGHT	1	27.8229	6.01	0.0260
Error	17	4.6263		

## Discussion

A relatively diverse dry-season invertebrate fauna, comprising 113 morphospecies from 51 families representing 12 different orders, was recovered from the tropical mistletoe *Decaishina signata* in the suburbs of Darwin. Moreover, the species accumulation curves and estimated total species richness, according to the incidence-based coverage estimator (Figure 3), show that the number of species is still increasing, indicating that our faunal inventory was incomplete. The ICE mean estimate was 229 species, which implies that only about half of the total fauna was sampled (i.e. a further 116 species are likely to occur on the mistletoe). These data are consistent with limited previous studies reported elsewhere in the world (Stevens & Hawksworth 1970; Room 1972a; Whittaker 1984) that show that mistletoes in both the Loranthaceae and Viscaceae support high numbers of invertebrates. The studies are not strictly comparable, because of differences in sampling intensity, seasonal timing and spatial area covered, but do serve to highlight the relatively large number



and broad range of spiders and insects associated with mistletoes in both temperate and tropical habitats. Nevertheless, there are some striking similarities in invertebrate taxonomic composition. Hymenoptera, Hemiptera, Araneae and Lepidoptera were relatively dominant in our samples in terms of both taxonomic richness and relative abundance, a finding which is in broad agreement with those of Room (1972a) and Whittaker (1984).

Interestingly, a high proportion of the total species associated with *D. signata* (53%,  $n = 60$ ) were rare, sampled from only a single site (Appendix), a finding that is similar to that of Room (1972a) who found that about two-thirds of all species collected from *Tapinanthus bangwensis* from Ghana were singletons. The large proportion of rare species associated with these two tropical mistletoes in northern Australia and West Africa parallels the general trend documented for tropical forests in which singletons are characteristic of herbivorous insect communities, often representing more than half of the species, even in large samples (Novotný & Basset 2000 and references therein). A proportion of these 'rare' taxa associated with *Decaishina* are probably transient (incidental) or represent an artefact due to insufficient sampling. However, other rare species may either be distributed in relatively low population density across the suburban landscape (suffusive rarity) or have a highly clumped pattern of distribution that is patchier than the spatial distribution of the mistletoe (Calder & Bernhardt 1983). Alternatively, some rare species may be diffusively rare (Schoener 1987; Novotný & Basset 2000), comprising generalists that rarely feed on *D. signata* but which are more abundant across other more preferred host plant species, or specialists that occasionally use *D. signata* but are more numerous on other mistletoe species.

Our preliminary survey from the NT of northern Australia and surveys carried out in Ghana (Room 1972a), Pakistan (Baloch & Ghani 1980) and southern Texas, USA (Whittaker 1984) suggest that insects and other invertebrates associated with mistletoes can be divided into six broad functional categories: transient, facultative generalists, obligate specialists, predators/parasitoids, scavengers/detritivores and mutualistic associates. Transient species are incidentals or 'tourists' that come into contact with mistletoes irregularly and are not dependant on the mistletoe or its associated fauna as a resource. Facultative generalists are those species that feed upon or use the plant in some way (e.g. ants utilising tunnels made by wood boring larvae), but are not necessarily dependent on the mistletoe for survival because they can utilise resources from other plant families. Obligate specialists are those species that feed exclusively on mistletoes (i.e. wood, leaves, flowers, fruits) and are dependant on the resource for survival. Predators and parasitoids include those species that prey on (e.g. spiders) or parasitise (e.g. wasps) other insects on mistletoes, while scavengers and detritivores include species which feed on dead organic matter. Mutualistic associates include participants in beneficial interactions such as ants attending scale insects for honeydew.

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In general, the basic natural history of the monsoon invertebrate fauna of northern Australia is too poorly known to assign functional roles to most invertebrates in our samples. Nonetheless, some comments on the ecology of the fauna are noteworthy. The Hymenoptera identified in this study provide a substantial list that is fundamentally different from that recorded from the dwarf mistletoes *Arceuthobium* (Stevens & Hawksworth 1970; Whittaker 1984), with numerous parasitic and mutualistic associates present. For example, the site with Chalcididae, a known endoparasite of Lepidoptera larvae, was the same site that contained a cohort of *Delias* larvae (Pieridae). The wasp families Encyrtidae, Scelionidae, Aphelinidae, Braconidae, Eulophidae, Elasmidae and Bethyidae probably parasitise Miridae and lepidopteran larvae (G. Brown, pers. comm.). Agaonidae are *Ficus* (Moraceae) specialists, but in this study one species was recorded at three different sites, all in flower, with no *Ficus* growing nearby; the appearance of this wasp at more than one site suggests that it was not a transient species. The three species of Tropiduchidae and Cicadellidae (Hemiptera), when present, were recorded in high numbers with all life stages present, indicating evidence of breeding. Among the Lepidoptera, several taxa from the families Pieridae and Lycaenidae are known obligate mistletoe specialists (Braby 2000), and our breeding records for the Immididae and Geometridae have not previously been recorded for the Loranthaceae (see Common 1990 for review of the Australian fauna). Among the Coleoptera, three unidentified species of Curculionidae were recorded each from different sites, but none comprised the ubiquitous mistletoe weevil *Metyrus albicollis* which resembles droppings of the Mistletoe Bird *Dicaeum hirundinaceum* (Shaw). Whittaker (1984) recorded Coccinellidae feeding on aphids (Aphididae) on *Arceuthobium*, but in this study Coccinellidae were sampled at six sites, with aphids present at only two of these. Chrysopidae (Neuroptera) larvae also feed on aphids as well as Cicadellidae, but no aphids or cicadellids were present at the respective sites.

Taxonomic richness was positively related to mistletoe fresh weight, indicating that larger clumps supported higher diversity. In contrast to expectations, there was no effect of host tree on the mistletoe invertebrate fauna. There are two alternative explanations for the lack of a clear host effect. First, the mistletoe invertebrate fauna may be different from that of the host tree with little or no overlap between the two groups; this hypothesis carries the prediction or implication that the mistletoe invertebrate fauna is specialised and independent of its host tree. Second, the mistletoe invertebrate fauna may be similar or even identical to that of the host tree, with the implication that mistletoes support a widespread generalised fauna that is also shared between taxonomically different host trees. Both hypotheses require further testing and comparative analysis, but consideration of the discussion above, host affiliations among the Lepidoptera sampled, and chemical differences among the host tree genera, implies that the first hypothesis is more likely.

In Australia, mistletoes are often considered by local authorities as a weed due to high levels of infestation in non-natural (suburban and semi-rural) landscapes, and are selectively removed by physical or chemical means as part of the eradication process (Minko & Fagg 1989; Fagg 1997). In the NT, for example, the Darwin City Council regards mistletoes as a weed and they currently remove them when they are found, despite the fact that all mistletoes in Australia are native and most are endemic to the continent (Barlow 1984). However, such practices should be discouraged given the importance mistletoes play in the ecosystem as a keystone resource (Watson 2001), the complex ecological interactions they facilitate (Room 1972b; Whittaker 1984; De Baar 1985b) and the wide range of invertebrates that they support, some of which are obligate specialists. In suburban landscapes such as Darwin, it is assumed that mistletoes fulfil a similar ecological role in maintaining local biodiversity. The suburban landscape of Darwin, compared with other capital cities in Australia, is rather unusual in that it has a low population density (c. 114,000 people, including its satellite city Palmerston and the outer rural area, distributed over an area of approximately 926 km<sup>2</sup>) and a relatively high proportion of natural vegetation within the urban matrix. In Queensland, the Brisbane City Council has recently begun implementing better practices of mistletoe management in suburban parks and street trees for the maintenance of biodiversity in the urban environment (Moss 2006). These practices include a moratorium on mistletoe removal and the protection of specific host trees that Brisbane residents bring to the Council's attention, and such practices ought to be adopted by other cities.

## Acknowledgements

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## Appendix. Data matrix summarising occurrence of taxa across sites.

This appendix may be viewed at:

<http://sites.google.com/site/ntfieldnaturalists/home/journal>.



Mistletoe invertebrates: left - the day-flying moth *Borthana cleis*; below - a butterfly, the Northern Pencil-blue *Candalides margarita gilberti*. (Michael Braby)



The mistletoe *Dacysmnia signata* is common on trees in urban Darwin: below right - with flower buds and a jumping spider, *Cosmophasis* sp. (Salticidae) (Tissa Ratnayake); below - inflorescence with open flowers (Michael Braby).



## A description of the primary habitat of the Purple-crowned Fairy-wren *Malurus coronatus coronatus* in the Victoria River District, N.T.

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### Abstract

The habitat of the Purple-crowned Fairy-wren in the Victoria River District is described, with particular reference to the density of the riparian grass *Chionachne gyathopoda*, based on 75 vegetation transects sampled in 39 fairy-wren territories. This paper also clarifies confusion about the primary habitat of the fairy-wren with respect to another riparian grass, *Muesithea rottboellioides*, which shares with *C. gyathopoda* the common name Canegrass. To assist successful management and conservation we provide a guide to correctly distinguish these two grasses and recommend the use of the common name Rivergrass for *C. gyathopoda* and Northern Canegrass for *M. rottboellioides*.

### Introduction

The Purple-crowned Fairy-wren *Malurus coronatus* is a small insectivorous passerine restricted to riverside vegetation in northern Australia. The western subspecies, *M. c. coronatus*, occurs from the Kimberley in Western Australia east to the Victoria River District (VRD) in the Northern Territory, and is currently listed as vulnerable both nationally by the Australian Government (Environment Protection and Biodiversity Conservation Act 1999) and in the Northern Territory (Territory Parks and Wildlife Conservation Act 2000).

The habitat relationships of the Purple-crowned Fairy-wren were studied in the Victoria River area, from 2001 to 2004 (van Doorn 2007b). Throughout the course of this study and subsequent correspondence with stakeholders, it was evident that confusion exists about the grass species constituting its preferred habitat in this area. This confusion has arisen as a result of the misapplication of scientific names based on common names and has been compounded by the fact that the Purple-crowned Fairy-wren utilises a number of grass species. Two species in particular are commonly

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cited as the preferred habitat of the Purple-crowned Fairy-wren: *Cbionachne cyathopoda* (F.Muell.) F.Muell. ex Benth. (Rowley & Russell 1997; Lewis 2002; van Doorn 2007a,b) and *Mnesithea rotthoellioides* (R.Br.) de Koning & Sosef (Rowley 1993; Rowley & Russell 1997; Horner & Trembath 2006).

The common name Canegrass has been widely used to describe a range of riparian grass species considered to provide habitat for Purple-crowned Fairy-wren (McGill 1970; Boekel 1979; Buckley 1986; Rowley 1988; Rowley 1993; Goodfellow & Stott 2001; Higgins *et al.* 2001; Flegg 2002; Pizzey & Knight 2003). As is often the case with common names, this represents a large number of species, many of which vary greatly in structure, ecology and distribution. In addition to *M. rotthoellioides* and *C. cyathopoda*, several other species have been referred to as Canegrass in association with the Purple-crowned Fairy-wren: *Ophiuros exaltatus* (Goodfellow and Stott 2001; Higgins *et al.* 2001), exotic Bamboo *Bambusa* sp. (Rowley 1993) and various *Sarga* (previously *Sorghum*) species (Goodfellow & Stott 2001).

The two riparian grasses, *C. cyathopoda* and *M. rotthoellioides*, are both widely distributed throughout tropical Asia and Australasia. In Australia, both species occur in northern Western Australia, Northern Territory and Queensland (Sharp & Simon 2002). Although widespread in geographic distribution, *C. cyathopoda* is typically narrowly restricted to alluvial banks of riversides (Petheram & Kok 2003). In contrast, *M. rotthoellioides* can be found in a wide variety of habitats associated with seasonal water. *C. cyathopoda* is a rhizomatous perennial grass, often forming dense entangled thickets along riparian corridors with average height of 2.7 m, although it can reach a height of up to 5 m (Table 1, Figure 1A) (Cowie *et al.* 2000). By comparison, *M. rotthoellioides* is a tussock perennial grass with foliage to 1.2 m that normally grows on upper banks with distinct gaps between plant bases (Figure 1B).

Here, we provide a description of the primary habitat of the western subspecies of the Purple-crowned Fairy-wren *M. c. coronatus* in the VRD with the particular aim of clarifying which riparian grass species provides its preferred habitat.

## Methods

Extensive areas of the Victoria River and its tributaries were surveyed to determine presence or absence of the Purple-crowned Fairy-wren from April 2001 through October 2003 (van Doorn 2007b). The broad habitat structure defined by Rowley (1993) was used in conjunction with stakeholder consultation to identify areas for survey. Survey sites were often determined by accessibility whilst encompassing a large extent of more than 170 km of river frontage. The presence of Purple-crowned Fairy-wrens was established using "play-back", a technique used to accurately survey territorial fairy-wren species. During the survey, we found the Purple-crowned Fairy-wren only along the Victoria River. Subsequently, five field sites were established along the Victoria River for intensive study (Figure 2). At each study site in addition



to mist-netting birds, one of the primary techniques for determining territory boundaries was by recording any territorial singing, either individually or as a duet. Additionally, birds were followed regularly to monitor breeding and record foraging observations, enabling us to determine territory boundaries of groups (van Doorn 2007b). During the 2002 season, family groups were followed extensively and any territorial behaviour recorded and marked using a GPS (Garmin GPS II Plus <15m).

**Table 1.** Characteristics and recommended common names of *Chionachne cyathopoda* and *Mnesithea rottboellioides*, adapted from Sharp and Simon (2002) using data held by NRETAS (JLC). Note that both these genera contain two species in the NT with the other species of both genera (*Chionachne hubbardiana* and *Mnesithea formosa*) being small annual plants compared to their robust perennial counterparts.

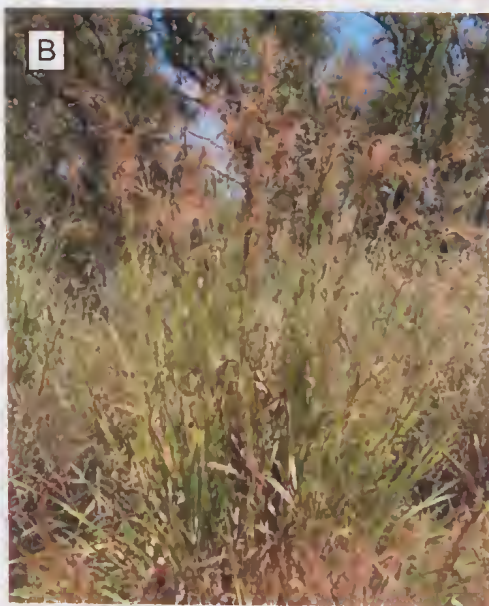
	Species	
	<i>Chionachne cyathopoda</i> Rivergrass	<i>Mnesithea rottboellioides</i> Northern Canegrass
<b>Habitat</b>	Banks and tributaries of large rivers	Grassland / woodland associated with seasonal water including creeks / wetlands perched on sandstone plateaus
<b>Soils</b>	Various, from sand to loam to clay	Generally sandy loam
<b>Gross plant morphology</b>	Rhizomatous perennial with stems branching and intertwining to 4 m high	Tussock perennial with leaves arising from base to 1 m high
<b>Leaf</b>	Relatively small	Large, forming bulk of plant
<b>Leaf attachment</b>	Throughout length of stem	From base of plant
<b>Reproductive (inflorescence) morphology</b>	Robust, enclosed by a prominent sheath; lower half of functionally female flowers, upper half of functionally male flowers	Fine, in groups near the end of a long stem; sheath subtending flower groups not prominent
<b>Reproductive (inflorescence) location</b>	Terminal or in leaf axils	Stem exerted from the plant base commonly to 2 m

At each of the five fixed study sites, we mapped vegetation using a point intercept method along 50 metre transects. Transects (where possible two in each fairy-wren territory) were set up diagonal to the bank, parallel to each other and at least 20m apart to ensure the maximum coverage of the habitat. At each metre intercept we recorded substrate as either plant species, bareground or debris (primarily leaves and dried *C. cyathopoda* blades, or dead trunk/branch), and also substrate height, canopy cover (species) and canopy height. All data were collected during the 2002 dry season (June-September) after fairy-wren territories had been identified. All sites had a similar

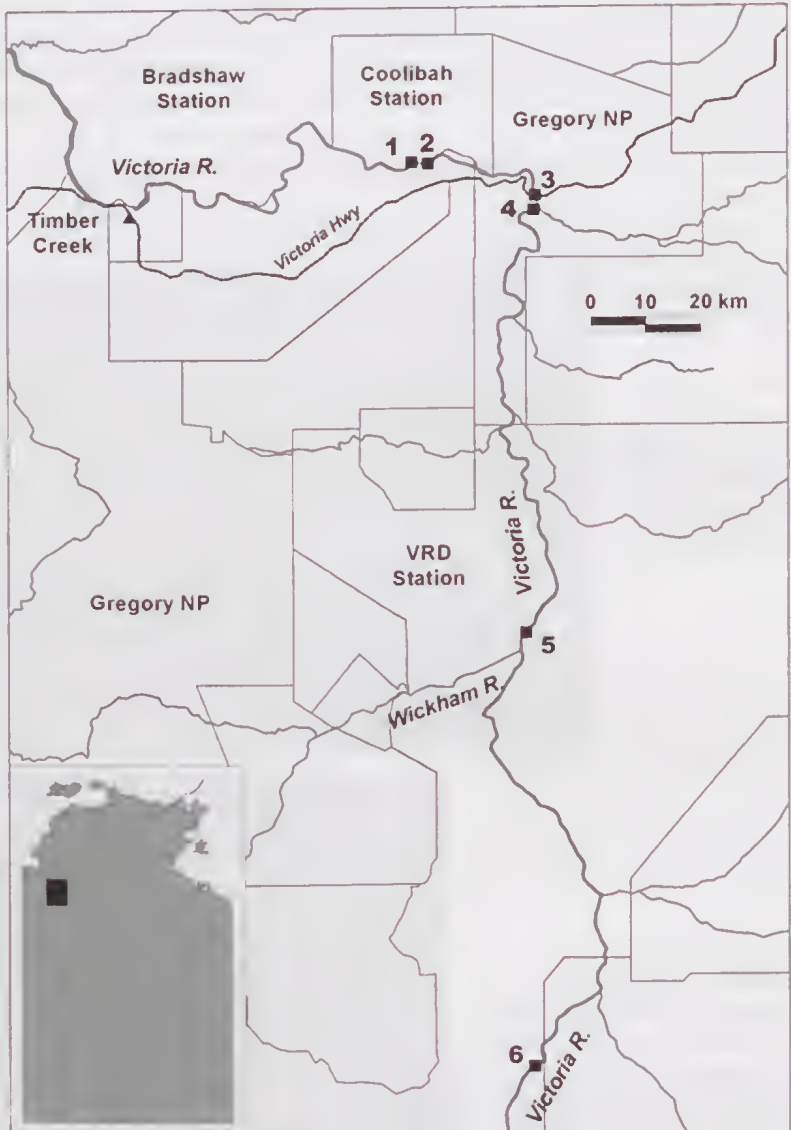


fire history (i.e. no fire for at least 2 years), although they did have varying grazing pressures. This time of year was chosen for logistical reasons as three of the sites were not accessible during the wet season. Further, this period coincided with the breeding season, when vegetation cover and structure might be particularly important for nesting and foraging.

Seventy five vegetation transects were sampled in 2002 in 39 fairy-wren territories at the five field sites. Twenty two transects (in 14 territories) were conducted at Coolibah, five (in three territories) at Dashwood, 14 (in seven territories) at Fitzroy, and 17 (in nine territories) at two sites in Gregory National Park. There were only a few territories at the Dashwood Crossing site accounting for the low number of transects at that site.



**Figure 1.** Comparative photographs taken along the Victoria River: A. Dense stand of Rivergrass *Chionachne cyathopoda* and B. Tussock of Northern Canegrass *Mnesithea rottboellioides*. (A. van Doorn)

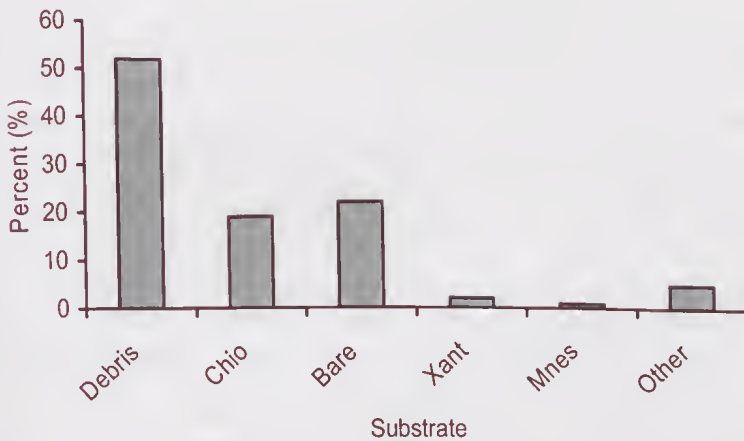


**Figure 2.** Location of study sites (1–5) (van Doorn 2007b) and additional site (no. 6) visited in 2008. 1. Fitzroy Station, 2. Coolibah Crocodile Farm, 3. Gregory National Park site 1, 4. Gregory National Park site 2, 5. Dashwood Crossing, Victoria River Downs Station, 6. Upper reaches of Victoria River. Indicated boundaries represent land tenure.

Results

Along the banks of the Victoria River the primary habitat of the Purple-crowned Fairy-wren is grasslands and/or woodlands with dense grass understorey dominated by *C. gyathopoda*. The dense stands formed by *C. gyathopoda* preclude most other vegetation and as such the habitat comprises largely of *C. gyathopoda*, debris and bare ground (Figure 3). *Chionachne gyathopoda* was present at all 75 transects and accounted for 19% of the understorey. Debris was the dominant non-vegetative cover and accounted for 53% of intersects (Figure 3). Debris was often very thick, especially at sites where *C. gyathopoda* was very dense. The average height of *C. gyathopoda* over all five sites was 2.5 metres. *Mnesithea rottboellioides* was recorded at nine transects and accounted for only 0.7% of the understorey. Weeds were common in the understorey and included Noogoora Burr (*Xanthium strumarium*), Castor Oil (*Ricinus communis*), and Wild Passionfruit (*Passiflora foetida*). At the study sites, Noogoora Burr was the most prevalent weed with an overall frequency of 2% (Figure 3). The low frequency and distribution of *M. rottboellioides* across transects, compared to *C. gyathopoda* supports the latter species being the preferred habitat of the Purple-crowned Fairy-wren.

The canopy layer comprised four tree species: *Eucalyptus microtheca* (Coolibah or Flooded Box), *E. camaldulensis* (River Red Gum), *Barringtonia acutangula* (Freshwater Mangrove) and *Ficus coronulata* (River Fig). The most common canopy species based on canopy cover were *E. microtheca* (58%), *E. camaldulensis* (27%), *Barringtonia* (6%) and *Ficus* (4%).



**Figure 3.** Groundcover frequencies (%) at study sites (n = 75). Debris = bare ground with debris, Chio = *Chionachne gyathopoda*, Bare = bare ground, Xant = *Xanthium strumarium*, Mnes = *Mnesithea roetbellioides*.

## Discussion

There exists considerable disagreement in the literature about which grass species is the primary habitat of the Purple-crowned Fairy-wren along the Victoria River. Some authors have stated that *M. rotthoellioides* is the primary habitat (Rowley 1993; Horner & Trembath 2006), while other authors have identified *C. gyathopoda* as the primary habitat (Rowley 1997; Lewis 2002). We suspect this discrepancy is a result of misidentification, confounded by these species sharing a common name. We resampled the sites visited by Horner & Trembath (2006) and Rowley (1993) and found the habitat to consist predominantly of *C. gyathopoda* and not *M. rotthoellioides* as stated in these papers. The possibility of a change in floristics during the intervening period is not likely given the ecology of both species, in particular the long establishment period required to form any significant stands of *C. gyathopoda*.

Although *M. rotthoellioides* did occur within some fairy-wren territories it was present in much lower densities than *C. gyathopoda*. Van Doorn (2007b) showed that although *M. rotthoellioides* is sometimes used as a nesting substrate, Purple-crowned Fairy-wrens showed a strong preference for *C. gyathopoda* for nesting; 85% (55) of nests were located in *C. gyathopoda*. The remaining nests were placed in *M. rotthoellioides* 14% (9), and one single nest (1%) was found in a *Barringtonia* sapling. During this same study, *C. gyathopoda* was also found to be a preferred foraging substrate (60% of observations) suggesting that in the VRD this grass species is critical in the conservation and management of the Purple-crowned Fairy-wren.

In the Kimberley (WA), Purple-crowned Fairy-wrens were found predominantly in *Pandanus aquaticus* habitat (Rowley 1993). Our surveys in 2001 through 2003 failed to locate fairy-wrens in *P. aquaticus* habitat in the lower reaches of the Victoria River (Bradshaw and Timber Creek upstream to the Victoria River Access in Gregory National Park, Figure 2). Thirty years ago, the Purple-crowned Fairy-wren was found in riparian areas dominated by *P. aquaticus* rather than dense grasses (Boeckel 1979) at some sites in the Victoria River system, notably the Wickham River near the Victoria River junction (Figure 2). Boeckel (1979) described the low density and patchy distribution of birds and expressed concern for the future survival of that population. A 2008 survey of this same area and the upper reaches of the Victoria River located Purple-crowned Fairy-wrens in *P. aquaticus* habitat. The distribution of both populations was fragmented and patchy (A. van Doorn, M. Damian & A. Northey unpubl.). During the 2008 survey, fairy-wrens at Dashwood Crossing which were previously located in *C. gyathopoda* were found using *P. aquaticus* habitat. At this location, *C. gyathopoda* had been almost completely destroyed by intense grazing with only very small clumps or individual plants left. It is possible that *P. aquaticus* is an important habitat component where *C. gyathopoda* habitat has been lost or degraded.

In the VRD, dense tall riverside stands of *C. gyathopoda* not only form the primary habitat for Purple-crowned Fairy-wren, but may also provide an important source of food for many other bird species. Large flocks of finches (e.g. Star Finch *Neochmia*



*ruficauda*, Crimson Finch *N. phaeton*, Yellow-rumped Mannikin *Lonchura flaviprymna* and Chestnut-breasted Mannikin *L. castaneothorax*) congregate in the grass when it is seeding (van Doorn 2007b).

Unfortunately, *C. gyathopoda* is heavily impacted by grazing and trampling in unfenced areas during the extended dry season when cattle congregate along the riparian corridor. This results in significantly reduced densities of Purple-crowned Fairy-wren at heavily grazed sites. Van Doorn (2007b) found that intensely grazed sites had an average *C. gyathopoda* height of 2.2 m compared to an average height of 2.7 m at ungrazed sites. In addition, grazed sites had higher frequencies of bare ground (20-42%) in comparison to ungrazed sites (8-12%). Moreover, monitoring of marked birds over two years demonstrated a decline in the annual survival rate of adult fairy-wrens from 90% to 26% following the introduction of grazing but no significant decline at a site that remained ungrazed throughout (van Doorn 2007b).

Hot fires (i.e. during the late dry season) also pose a threat to the Purple-crowned Fairy-wren especially where *C. gyathopoda* occurs in long continuous stretches along the river. Although *C. gyathopoda* regenerates quickly, a reduction of Purple-crowned Fairy-wren density is evident, most likely as a result of direct mortality and increased predation due to lack of suitable cover after such an event (van Doorn 2007b, A. van Doorn unpubl. data). Preliminary data also suggest that breeding may be affected for up to two seasons after a hot fire (A. van Doorn, unpubl. data).

Currently, the riparian zone along the Victoria River is under multiple tenures and land uses; these include areas devoted to conservation (Gregory National Park), defence (Bradshaw Field Training Area), pastoralism and Aboriginal land uses. There has recently been an increase in the conservation initiatives for the Purple-crowned Fairy-wren among all these tenures and an understanding of the primary habitat of this species is essential for any management strategies (e.g. van Doorn 2007a, 2008).

Major road works affecting fairy-wren habitat along the Victoria River have recently commenced, necessitating removal of approximately one hectare of Purple-crowned Fairy-wren habitat. Actions to mitigate the impacts of this disturbance include monitoring Purple-crowned Fairy-wren habitat and implementing management strategies to improve habitat along the Victoria River.

In order to establish successful management and conservation plans for the Purple-crowned Fairy-wren in the VRD, it is essential that the primary habitat is accurately identified. Confusion that has arisen in regard to the common name Canegrass as it applies to the Purple-crowned Fairy-wren habitat illustrates the importance of species identification and the use of scientific names. Although use of the common name Canegrass is valuable during communications with local stakeholders, it is extremely important to identify the correct species to avoid confusion that may hinder conservation or management strategies.

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Whilst acknowledging that the name Canegrass is well entrenched with respect to *C. gyathopoda* we reinforce the following preferred common names and recommend that these names are consistently applied and always accompanied by their correct scientific name; Rivergrass for *Chionachne gyathopoda* and Northern Canegrass for *Mnesithea rottboelliioides* (Sharp & Simon 2002). To ensure these two grass species are correctly identified we provide the means to distinguish the two grasses through the summary of morphological and ecological characteristics in Table 1 and photographs of each species in Figure 1.

## Acknowledgements

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Purple-crowned Fairy-wren pair (female above; male below) among Rivergrass *Chionachne cyathopoda* along the Victoria River. (A. van Doorn)



## Seasonality of nectar production by woodland plants on the Gove Peninsula

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### Abstract

In this paper I report flowering periods and indices of nectar availability over two years, for seven common plants regarded as being important nectar resources for birds in savannah woodland and rehabilitated mined land on the Gove Peninsula. Nectar availability varied seasonally, being lowest from December to February and highest in June and October each year. Nectar availability differed significantly between years, the difference being predominantly attributable to eucalypts, which exhibited large inter-annual differences in flowering, in contrast to the more consistent flowering of non eucalypts. Fern-leaved *Grevillea* contributed most to the nectar index (30%) across study sites. Darwin Stringybark contributed 10% to the overall nectar index, although this is considered an underestimate of its importance to nectar availability on the Gove Peninsula. Although birds were observed feeding on the nectar of all plant species for which the nectar index was calculated, Fern-leaved *Grevillea* (8 bird species) and Darwin Woollybutt (7 bird species) attracted the largest variety of birds.

### Introduction

Nectar is a food source for a large group of vertebrates, especially birds (particularly honeyeaters and lorikeets) and flying foxes (Pyke 1985; Woinarski *et al.* 1997). As a food source nectar is noted for its temporal and spatial variability, and this is particularly the case in the monsoon or wet-dry tropics (e.g. Franklin & Noske 1999; Williams *et al.* 1999; Woinarski *et al.* 2000). The Australian wet-dry tropics are characterised by seasonal rainfall with a distinct wet season from November to April, when approximately 85% of the mean annual rainfall falls (1713 mm at Darwin Airport, 1467 mm at Gove Airport), and a dry season from May to October. In the northern tropical savannas of Australia nectar availability peaks in the dry season associated with flowering in open eucalypt forests, especially those co-dominated by Darwin Stringybark *Eucalyptus tetradonta* and Darwin Woollybutt *Eucalyptus miniata* (Franklin & Noske 1999; Williams *et al.* 1999; Woinarski *et al.* 2000). Darwin

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Stringybark and Darwin Woollybutt both produce high energy yields of nectar, and the richest avian nectarivore community in Australia has been documented in a tropical savannah dominated by these tree species (Franklin 1994). Specialist nectarivores in this community are augmented by numerous other bird species taking advantage of the seasonal abundance of nectar (Franklin 1999).

Knowledge of fluctuations in resource availability in northern Australia is scant and mostly localised (Brooker *et al.* 1990; Woinarski & Tidemann 1991; Franklin & Noske 1999; Woinarski *et al.* 2000) and I know of no published data from the Gove Peninsula. The Gove Peninsula is approximately 650 km east of the Darwin region where most studies of flowering period and nectar availability in the Top End have taken place. The wet season on the Gove Peninsula is of similar duration but occurs later than in Darwin (Figure 1) and therefore it may be expected that there would be differences in the timing of flowering of individual species between the two locations.

In this paper I report the timing of flowering and provide indices of nectar availability for some common plants over a two-year period. These plants are regarded as important nectar sources for birds in the savannah woodland of the Gove Peninsula. These species have large flowers and were known, from the literature and from prior observations of the author and R. A. Noske, to be frequented by nectarivorous birds. Birds feeding on each of the plant species during the study period were recorded opportunistically and data are presented here. Seasonal and inter-annual comparisons of nectar availability were made and the relative contribution of eucalypts examined. Data were recorded as part of a study comparing the avifauna and their food resources of the rehabilitation areas with those of surrounding woodland on the Alcan mineral lease.

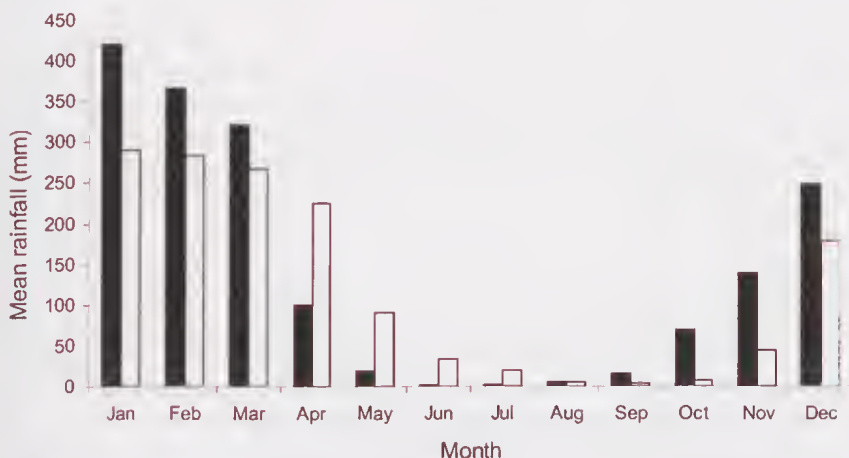


Figure 1. Mean monthly rainfall (mm) at Darwin Airport (black bars) and Gove Airport (white bars) (Bureau of Meteorology 2009).



## Methods

This study was conducted on rehabilitated mined land and surrounding undisturbed areas on the Alcan mineral lease on Gove Peninsula (12°16'S, 136°49'E) in north-eastern Arnhem Land, Northern Territory, Australia. Plant communities of the rehabilitated land varied from *c.* 3-8 year old shrubland (dominated by acacias, Fern-leaved Grevillea *Grevillea pteridifolia* and Red Grevillea *Grevillea heliosperma*) to low open forest (approximately 8 to 25 years old) whose canopy was dominated by Darwin Stringybark and Darwin Woollybutt (Brady 2005). The canopy of open forests surrounding the mining lease is dominated by Darwin Stringybark.

Flower abundance was observed at 36 spatially separate 30m x 30m quadrats every second month for two years between December 1998 and October 2000. Thirty quadrats were in vegetation rehabilitated by direct seeding after cessation of mining. These were spread evenly across successional stages, ranging from 3 to 25 years since rehabilitation commenced. Six quadrats were placed in the open forest adjacent to the rehabilitated vegetation.

Flower abundance was recorded for individuals of seven plant species deemed the most important for birds in the study area (Table 1); these included large and small trees and a climber. Large trees were the canopy species Darwin Stringybark, Darwin Woollybutt and Long-fruited Bloodwood *Corymbia polycarpa*. Small trees were Fern-leaved Grevillea, Red Grevillea and Red-flowering Kurrajong *Brachyebiton paradoxus*. Red-flowering Kurrajong grew to considerable size in the absence of fire in rehabilitation areas, some specimens being over 8 m in height, in contrast to the stunted form common in regularly burnt woodland. Flowering of the naturalised climber Wild Passionfruit *Passiflora foetida* was also monitored.

The quantity of flowers on each individual tree was scored on a 1 to 3 scale, 1 being a small number of flowers and 3 being a large number of flowers. The size of the plant was considered in allocating scores; a small tree with many flowers may receive the same score as a large tree with few flowers. All species under study were considered when assigning scores, so that even a large, heavily flowering specimen of the Red-flowering Kurrajong would never receive a score of 3 because it was never as large as the canopy eucalypts.

To calculate an index of nectar availability that incorporates the amount of nectar produced by flowers (in addition to the number of flowers), the "expert score" of flowering intensity reported by Woinarski *et al.* (2000) was used as a multiplier (Table 1). This score was derived by asking experts to score species against each other based on their attractiveness to vertebrates, which was assumed to correlate with the amount of nectar produced by a flower and the quantity of flowers produced. (The exception was *P. foetida*, which was assigned a score after discussion with J.C.Z. Woinarski). A nectar availability index was calculated by multiplying the score of flower abundance by the expert score. Although admittedly a poor substitute for direct



**Table 1.** Observations on monitored nectar-producing plant species, with expert score and bi-monthly nectar index. Data are also given for the number of quadrats in which species were present and for the number of individuals of flowering maturity across all quadrats (except for *P. foetida*, individuals of which were not counted as it grew in a tangled mat). The number of bird species opportunistically observed feeding on each species during the study period are shown.

	<i>Grevillea pteridifolia</i>	<i>Eucalyptus miniata</i>	<i>Grevillea heliosperma</i>	<i>Eucalyptus tetradonta</i>	<i>Brachychiton paradoxus</i>	<i>Corymbia polycarpa</i>	<i>Passiflora foetida</i>	Total
No. quadrats	18	25	18	17	16	5	15	36
No. individuals	100	86	66	56	68	11	0	387
Expert score	9.7	9.5	7	7	5.2	9	3	
No. bird species	8	7	3	2	1	2	2	
<b>Bi-monthly nectar index</b>								
Dec. 1998	0	0	70	0	0	0	0	70
Feb. 1999	0	0	42	0	0	0	0	42
Apr. 1999	0	95	280	0	0	0	0	375
Jun. 1999	0	361	805	7	0	0	0	1173
Aug. 1999	426.8	9.5	42	0	130	0	0	608.3
Oct. 1999	1755.7	9.5	7	0	457.6	0	0	2229.8
Dec. 1999	0	0	0	0	0	0	3	3
Feb. 2000	0	19	49	0	0	135	129	332
Apr. 2000	0	731.5	336	7	0	297	105	1476.5
Jun. 2000	0	2061.5	574	0	5.2	0	0	2640.7
Aug. 2000	184.3	133	105	1344	197.6	0	0	1963.9
Oct. 2000	1522.9	0	77	0	390	0	0	1989.9
<b>Total</b>	<b>3889.7</b>	<b>3420</b>	<b>2387</b>	<b>1358</b>	<b>1180.4</b>	<b>432</b>	<b>237</b>	<b>12904.1</b>

measurement of the amount of nectar produced by flowers, using the expert score as a multiplier includes attractiveness of flowers (nectar production) in the index of nectar availability. As the expert score also considers the quantity of flowers, the index is weighted more heavily towards the abundance of flowers than their attractiveness.

The index of nectar availability for each species for each month was calculated by multiplying the index of flower abundance (1 to 3) by the expert score for each flowering individual, and adding together the scores for all flowering individuals. Indices of nectar availability have been used in other studies of nectarivorous birds in northern Australia (e.g. Woinarski & Tidemann 1991, Woinarski *et al.* 2000).

The number of bird species feeding on flowers includes only observations of birds probing flowers in the region of the nectaries and exhibiting behaviour consistent with swallowing a liquid.

To compare nectar availability between months each quadrat was treated as a replicate and the Kruskal Wallis Medians Test was employed to test for statistical significance. To compare nectar availability between years, data for the six months of each year was pooled for each quadrat and a *t*-test for matched pairs used to test for statistical significance.

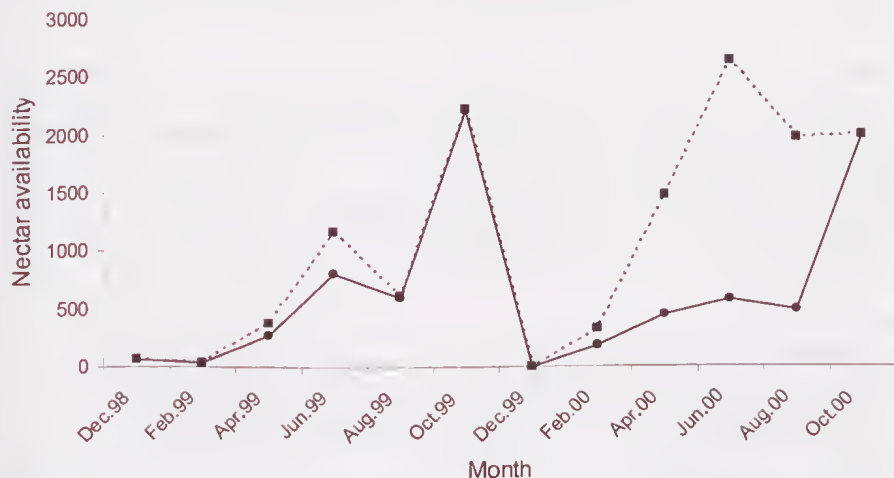
## Results

Nectar was present year round, although the amount varied seasonally, with very low nectar availability from December to February, increasing from the late wet and peaking in the dry season. The index was highest in June and October each year (Table 1, Figure 2). The difference in the index of nectar availability between months was statistically significant (Kruskal Wallis;  $n = 432$ ,  $H = 77.2$ ,  $P < 0.001$ ), as was the difference in nectar availability between years (*t*-test for matched pairs,  $df = 35$ ,  $t = 3.5$ ,  $P < 0.001$ ) with more nectar available in the second year. The difference between years was also significant when only data from the open forest is considered (*t*-test for matched pairs,  $df = 5$ ,  $t = 2.1$ ,  $P < 0.05$ ).

Eucalypts contributed a little over half to the nectar availability index, the vast majority of which was contributed during the second dry season (Figure 2, Table 1). For non eucalypts, nectar availability followed a much more consistent pattern between years, increasing from a wet season low to a peak in October (Figure 2).

The Red Grevillea flowered most consistently, with flowers recorded in all survey periods except December 1999 (Table 1). Fern-leaved Grevillea contributed most to the nectar index across the study sites, making up 30% of the total nectar index. Fern-leaved Grevillea was recorded flowering during August and October, with a similar nectar index, in both years (Table 1). Darwin Woollybutt made the next largest contribution to the nectar index (26%). Although Darwin Woollybutt produced nectar in the dry season during both years, the nectar index was more than 6 times higher in

the second year. Darwin Stringybark and Long-fruited Bloodwood followed a similar but more pronounced pattern with little or no flowering recorded in the first year and a large flowering in the second year (Table 1). Red-flowering Kurrajong was more consistent between years and contributed to the mid to late dry season peak in the nectar index. Wild Passionfruit contributed little to nectar availability although it was the only species recorded flowering during December 1999 (Table 1).



**Figure 2.** Index of nectar availability for all plant species combined (dashed line with squares) and for non eucalypt species combined (solid line with circles).

Birds were observed feeding on the nectar of all plant species for which the nectar index was calculated (Table 1). Fern-leaved Grevillea (8 species) and Darwin Woollybutt (7 species) attracted the most bird species (Table 1). Thirteen bird species were recorded drinking nectar over the study period, six of which were honeyeaters and two lorikeets (Table 2). Five species were not specialist nectarivores but were opportunistically feeding on nectar. These were Grey Butcherbird *Cracticus torquatus*, Little Corella *Cacatua sanguinea*, Spangled Drongo *Dicrurus bracteatus*, Sulphur-crested Cockatoo *Cacatua galerita*, and Torresian Crow *Corvus orru*.

## Discussion

The seasonal variation in nectar availability, with much more nectar available in the dry season, conforms to other studies from open forest and woodland in the Top End (Setterfield & Williams 1996; Franklin & Noske 1999; Williams *et al.* 1999). These results contrast with the drier more inland deciduous woodland, where Woinarski and Tidemann (1991) found flowers were present all year, but were more abundant and

diverse in the wet season and transitional months. Franklin and Noske (1999) found the dawn standing crop of nectar, in eucalypt woodland south of Darwin, varied 60-fold through the year, with a low in March and a peak flowering period from mid June to early August. The slight difference in times of peaks and troughs, later on the Gove Peninsula, may be result of the timing of the wet season, being later on the Gove Peninsula (Figure 1). The timing of flowering of one species, Fern-leaved Grevillea, was much later on the Gove Peninsula where it peaked in October compared to the June/July peak reported from woodland near Darwin (Franklin & Noske 1999, 2000).

Table 2. Bird species recorded feeding on nectar.

Honeyeaters	Lorikeets	Opportunists
Banded Honeyeater <i>Certhionyx pectoralis</i>	Rainbow Lorikeet <i>Trichoglossus haematodus</i>	Grey Butcherbird <i>Cracticus torquatus</i>
Brown Honeyeater <i>Lichmera indistincta</i>	Varied Lorikeet <i>Psittuteutes versicolor</i>	Little Corella <i>Cacatua sanguinea</i>
Dusky Honeyeater <i>Myzomela obsura</i>		Spangled Drongo <i>Dicrurus bracteatus</i>
Little Friarbird <i>Philemon citreogularis</i>		Sulphur-crested Cockatoo <i>Cacatua galerita</i>
Silver-crowned Friarbird <i>Philemon argenteiceps</i>		Torresian Crow <i>Corvus orru</i>
White-throated Honeyeater <i>Melithreptus albogularis</i>		

The difference in nectar availability between years is predominantly attributable to the eucalypts as they exhibited large inter-annual differences, in contrast to the more consistent flowering of non eucalypts. A statistically significant difference between years was still present when the open forest was considered separately, discounting the possibility that the difference was a result of trees in rehabilitation areas being a year older and thus more productive in the second year of the study. Although sampling occurred every second month there was no evidence (e.g. buds and fruit) that there had been an extensive flowering of eucalypts between sampling periods. Inter year differences in eucalypt flowering has been reported from other areas of the Top End, with Setterfield and Williams (1996) reporting an approximately two-fold difference for Darwin Woollybutt and three-fold for Darwin Stringybark. They reported a good flowering for each species 1 in 3 years. This pattern of among year variation in flowering has been described for many other eucalypts (Hillis & Brown 1978; Law *et al.* 2000; Birtchnell & Gibson 2006). Extended periods between flowerings may be a result of individuals needing time to accumulate sufficient resources (Ashton 1975; Birtchnell & Gibson 2006) although this does not account for the simultaneous flowering of numerous individuals.

The contribution of Darwin Stringybark to the overall nectar index (10%) greatly underestimates its importance when considering the region around the study area. The open forest and woodlands of the Gove Peninsula are overwhelmingly dominated by Darwin Stringybark. However, 30 of the 36 quadrats used to calculate the nectar index were in rehabilitation areas, thereby favouring faster maturing trees such as Fern-leaved Grevillea over slower growing eucalypts. Although the species sampled in this report would contribute the vast majority of nectar available to vertebrates in the open forest and woodlands of the Gove Peninsula, nectar would be available in other unsampled habitats such as *Melaleuca*-dominated swamps, mangroves and rainforests.

The high proportion that Fern-leaved Grevillea contributed to the nectar index is unsurprising as this species is noted for its prolific nectar production. Franklin and Noske (1999) reported nectar dripping to the ground from this species on their study site at the Territory Wildlife Park. This tree had the highest richness of bird species feeding on the nectar, including a number not usually nectarivorous, namely Grey Butcherbird, Little Friarbird, Spangled Drongo, Sulphur-crested Cockatoo and Torresian Crow. This opportunistic nectarivory has been reported from other parts of the monsoon tropics (Franklin 1999).

Long-fruited Bloodwood flowered in February and April of the second year of the study. This coincided with the presence of Banded Honeyeater and Varied Lorikeets in the study area (Brady 2005). Keast (1968) considered these two species the "blossom nomads" of the Australian woodland, and large nectar-correlated congregations have been reported in the Top End by Franklin (1996) and Woinarski and Tidemann (1991).

The consistent flowering of Red Grevillea may make it a very important source of nectar during times of low nectar abundance. Similarly Wild Passionfruit, although contributing little to overall nectar abundance, may be an important resource for resident nectarivores in times of low nectar abundance.

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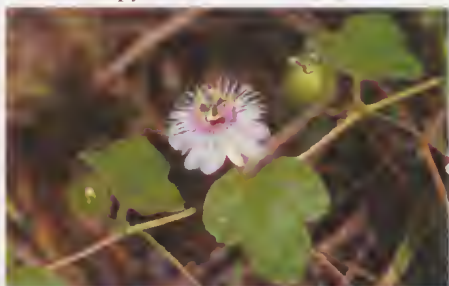
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Sources of nectar for birds (clockwise from above): Fern-leaved Grevillea *Grevillea pteridifolia* (TR); Red-flowered Kurrajong *Brachybiton paradoxus* (DF); Wild Passionfruit *Passiflora foetida*, an introduced species (TR); Darwin Woollybutt *Eucalyptus miniata* canopy (DF), close-up of flowers (TR).



Photographers:  
TR = Tissa  
Ratnayake;  
DF = Don  
Franklin.



Birds at flowers (clockwise from above):  
Brown Honeyeater (TC); Rainbow  
Lorikeet (TR); Sulphur-crested Cockatoo  
(TR); White-throated Honeyeater (TR);  
Spangled Drongo (TC).

Photographers: TC = Trevor Collins;  
TR = Tissa Ratnayake.





# **Evidence for predation on terrestrial Cane Toads *Bufo marinus* by the Sooty Grunter *Hephaestus fuliginosus* in northern Australia**

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## **History**

The Cane Toad *Bufo marinus*, a native of Central and tropical South America, was introduced to northern Queensland in 1935 as a biocontrol agent and is currently colonizing much of the Australian continent. With toxin-based anti-predator defences evident throughout all life history stages, the impacts of Cane Toad invasion on indigenous fauna, particularly naïve frog-eating predators, have attracted considerable scientific interest. Cane Toads have been implicated in declines of a range of vertebrate fauna throughout northern Australia, both anecdotally (Burnett 1997; White 2003) and quantitatively (Doody *et al.* 2006; Letnic *et al.* 2008). Much field survey effort regarding Cane Toads has focused on the potential impacts of toads on terrestrial and semi-aquatic vertebrates (reptiles and mammals), with evidence of effects, negative or otherwise, on native fish very rare in the Australian scientific literature. There are, however, recent accounts attributing fish kills in aquatic ecosystems in the Northern Territory to Cane Toads (Wilson 2004; Anon. 2006; Grace & Sawyer 2008). The Sooty Grunter *Hephaestus fuliginosus* is a widespread northern Australian freshwater fish with considerable ecological, recreational and spiritual importance (Pusey *et al.* 2004). Noted as an amphibian predator (Allen *et al.* 2002), the Sooty Grunter would accordingly be expected to be a significant Australian fish species potentially susceptible to toad toxicity. The following account documents predation on the terrestrial life history stages of Cane Toads by Sooty Grunters in northern Australia freshwater ecosystems, apparently with minimal evident adverse effect on the fish in question.

## **Observations**

During the course of fish surveys conducted across northern Australia in 2007, anecdotal accounts emerged from discussions with landholders in the Calvert River catchment, Northern Territory, of predation on adult Cane Toads by Sooty Grunter in local rivers. Cane Toads were first documented in the Calvert River region in 1986, following a westerly expansion from Queensland (Alford *et al.* 1995). On several occasions, cursory examination by landholders of stomach contents of Sooty Grunter captured through recreational angling on the Calvert River at Pungalina Station

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revealed anuran remains reportedly readily recognizable as adult Cane Toads. Subsequent stomach content analysis by one of us (AMD) of Sooty Grunter specimens collected from western Gulf of Carpentaria rivers during July 2007 strongly supported these observations, with the digested remains of adult toads found in the stomachs of two large fish. The remains of a juvenile Cane Toad (snout-vent length approx. 40 mm) comprising skeleton, tissue and skin fragments were found in a 285 mm standard length Sooty Grunter collected from the Calvert River near Calvert Hills station (17°18.077'S, 137°29.494'E). The partial anterior remains including forelimbs and pectoral girdle of a larger juvenile-small adult toad (snout-vent length approx. 70 mm) were also found in a 265 mm standard length Sooty Grunter specimen captured in the nearby MacArthur River (16°8.322'S, 136°17.590'E).

## Discussion

The remains of toads in fish stomachs and anecdotal accounts by fishermen of toad predation suggest consumption of Cane Toads by large Sooty Grunter may not be an uncommon occurrence in rivers of the Gulf of Carpentaria. In both cases in which toad remains were discovered in fish stomachs, the toads were well digested, suggesting ingestion had occurred at least several hours previous to collection, with fish displaying no obvious signs of poisoning prior to capture. Similarly, the anecdotal counts of toad remains in fish stomachs were derived from fish captured by bait and lure fishing, with the continuity of feeding behaviour by fish likewise suggestive of minimal toxic effect associated with toad consumption. These findings add the Sooty Grunter to the relatively limited number of known predators of Cane Toads in Australia (Covacevich & Archer 1975; Alford *et al.* 1995).

The dietary ecology of Sooty Grunter is characterized by marked ontogenetic transitions in diet, with shifts toward an array of terrestrially derived prey types (invertebrates, terrestrial vegetation and terrestrial vertebrates) in larger size classes. In addition to Cane Toads, a diversity of nominally terrestrial vertebrates such as small snakes, lizards, mammal and bird remains have also been recorded from Sooty Grunter stomach content analysis (A. Davis, unpubl.), indicating opportunistic predation on virtually any small terrestrial vertebrate encountered in the aquatic environment. With the high abundance of Cane Toads in many aquatic-riverine environments in the wet-dry tropics of northern Australia (White 2003), and their need for more frequent in-stream rehydration there compared to in wetter bioclimatic regimes (Letnic *et al.* 2008), encounters between Cane Toads and opportunistic fish predators such as Sooty Grunter are probably relatively frequent. While Cane Toad – Sooty Grunter encounters may be frequent, the level of predation of toads by these fish remains unknown.

Predation on the terrestrial life history stages of Cane Toads is particularly interesting in light of the aversion and learned avoidance of consumption of Cane Toad tadpoles documented for a number of Australian freshwater fish, including Sooty Grunter,



during previous feeding experiments (Alford *et al.* 1995; Crossland 2001). Anecdotal accounts also exist of Sooty Grunter deaths from exposure to Cane Toad toxins in Northern Territory aquatic ecosystems (Wilson 2004). Issues relating to factors such as the actual toxicity of adult toads to various fish species, the role of hunger in shaping predatory behaviours of the Sooty Grunter, and possible longer-term selective pressures imposed on aquatic predators following toad invasion remain unstudied.

The occurrence of predation on adult toads by other Australian freshwater fish species with relevant physical capabilities and dietary habits remains essentially unknown. Past research has focused predominantly on the toxicity or palatability to fish of Cane Toad eggs and tadpoles rather than terrestrial life history stages. There are accounts of at least one other northern Australian fish, the Jungle Perch *Kribia rippestris*, feeding on adult toads (both direct observation and toad remains identified from stomach content analysis) with negligible effect evident (Covacevich & Archer 1975). Cane Toad colonization has recently expanded into the distributional range of the Sooty Grunter's closely related congener *Hephaestus jenkinsi*, an ecologically comparable species that similarly preys upon frogs and other vertebrates (A. Davis, unpubl.). A range of additional northern Australian fish species, such as Saratoga *Schlerophages jardinii*, Barramundi *Lates calcarifer* and ariid catfishes, opportunistically consume terrestrial vertebrates so presumably these species would encounter adult toads as potential prey. The outcomes of such predator-prey interactions are yet to be documented. How predatory fish guilds respond to toad invasion constitutes one of the many gaps in understanding the community level effects of toad colonization in Australia. In contrast, the drastic population declines observed in some other vertebrate predators has been well reported (Doody *et al.* 2006; Letnic *et al.* 2008).

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Though poisonous to many that attempt to consume them, the Cane Toad *Bufo marinus* is food for some native species including the Sooty Grunter. (Tissa Ratnayake)

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## False Killer Whales *Pseudorca crassidens*: regular visitors to Port Essington and Darwin Harbour in the Northern Territory, Australia

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### Introduction

Until recently there has been very little cetacean research undertaken in the Northern Territory (NT) (Chatto & Warneke 2000; Palmer *et al.* 2009). However, since 2007 the Coastal Dolphin Project has been focussing on the three species of coastal dolphins (Australian Snubfin *Orcaella heinsobni*, Indo-Pacific Humpback *Sousa chinensis* and Indo-Pacific Bottlenose *Tursiops aduncus*) and undertaking a range of research activities including monthly boat-based surveys at three sites in the NT: Coburg Marine Park, Darwin Harbour and the Alligator Rivers region. As the Coastal Dolphin Project has gained a profile both publicly and within various government agencies and non-government organisations, a further benefit has been the recording, reporting and collation of information on a typically ocean-going dolphin that appears to be a regular visitor to both Port Essington and Darwin harbours, the False Killer Whale *Pseudorca crassidens*.

The False Killer Whale is one of the larger members of the dolphin family, Delphinidae, and despite its world-wide distribution throughout the tropics and subtropics, is one of the least known of the large tropical oceanic dolphins (Odell & McClune 1999) (Table 1). Adult male False Killer Whales can reach up to 6 m in length and females to 5 m (Baird 2008). The common and scientific names relate to the similarity in skull morphology to the Killer Whale (*Orcinus orca*), but the two species are not closely related.

In most parts of their range, False Killer Whales are usually far from shore, though there have been occasional exceptions, and individuals have been recorded on the west coast of Vancouver Island in Barley Sound, Canada (Stacey & Baird 1991). The only other areas where False Killer Whales are frequently seen close to the shore are near tropical oceanic islands (Acevedo-Guitierrez *et al.* 1997; Baird *et al.* 2008). In

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particular, genetic evidence suggests a demographically isolated population around the main Hawaiian Islands (Baird *et al.* 2008; Chivers *et al.* 2007).

Table 1. Characteristics of the False Killer Whale (from Baird 2008).

Distribution	Found in all tropical and warm temperate oceans. Typically pelagic but approaches close to shore around oceanic islands.
Abundance	No estimates of global populations available but appear to be uncommon throughout their range.
Ecology	Known to mass strand. Feed on a variety of oceanic squid and fish and have been recorded feeding on small dolphins that have been released from tuna-purse seines.
Behaviour	Particularly social usually travelling in groups of 20 to 100 individuals. Strong bonds among individuals and long-term associations (15 years have been recorded).
Life history	Based entirely from stranded animals - both sexes thought to mature between 8 to 14 years of age. Longevity estimated around 57 years for males and 62 years for females. Calving interval potentially 7 years.
Anthropogenic threats	Small numbers have been taken directly and incidentally as bycatch, including by the gill-net fishery in northern Australia (Bannister 1977). In Hawaiian waters the longline fishery is thought to be having a major impact on longterm viability of the population. Have been recorded ingesting plastic. High levels of toxins documented in tissues from stranded animals.

Recent aerial surveys around the main Hawaiian Islands suggest that the population of False Killer Whales has declined considerably since the late 1980s (Reeves *et al.* 2009). Causes for the decline are not clear though incidental mortality in fisheries (both inshore and offshore) and potential reduction in prey availability (Reeves *et al.* 2009) could be factors in their decline.

## Observations

In the NT, eight sightings of False Killer Whale schools within the semi-closed harbours of Port Essington and Darwin have been collected or directly recorded since 2007 as part of monthly surveys undertaken by the Coastal Dolphin Project (Figure 1 & 2; Table 2). All recent sightings within these NT harbours have been recorded during the wet season (December – April). The behavioural observations associated with these sightings suggest the False Killer Whales were chasing schools of fish. There are two other pre-2007 sightings for Port Essington (20+ including young, 11<sup>th</sup> June 2003, R. Chatto pers. comm.; > 20, 10<sup>th</sup> October 2004, P. Fitzgerald pers. obs.) that were both outside the wet season.





Figure 1. Locations of four False Killer Whale sightings (●) in Port Essington (Cobourg Peninsula) 2008 to 2009.



Figure 2. Locations of four False Killer Whale sightings (●) in Darwin Harbour 2007 to 2009.



Table 2. Recent (2007 to 2009) sightings of False Killer Whales in the Northern Territory.

Area	Date	Number recorded
Port Essington	April 2008	80
Port Essington	December 2008	20
Port Essington	March 2009	> 8 (plus young)
Port Essington	April 2009	> 25
Darwin Harbour	April 2007	> 12
Darwin Harbour	January 2008	> 10
Darwin Harbour	March 2009	> 20
Darwin Harbour	April 2009	> 20

## Conclusion and Recommendations

Information on how cetacean populations are structured within their environments is essential for developing conservation and management plans. In the past it was believed that pelagic cetaceans have large continuous distributions with no apparent impediments to their movements. With the growing number of studies that focus on genetics, morphology and tagging of cetacean species, there is increasing evidence of population sub-structure in coastal, pelagic and migratory cetaceans (Chivers *et al.* 2007). Further, previous literature does not consider estuarine situations as essential habitat. The sightings reported here call for a reassessment of the importance for False Killer Whales of estuarine habitats, and whether such use is opportunistic or essential to False Killer Whale survival through the tropical wet season. Wide-ranging pelagic species like the False Killer Whale are inherently difficult and expensive to study. Nonetheless, the NT could be in ideal position to contribute to understanding False Killer Whale stock structure and thus contribute to defining appropriate geographical scales for management of populations (i.e. Evolutionary Significant Management Units) (Moritz 1994; Palsboll *et al.* 2007). The False Killer Whales recorded in the NT could potentially be a demographically isolated population and therefore warrant further investigation.

In order to contribute to the global understanding of this large pelagic dolphin, the Coastal Dolphin Project will opportunistically try to collect skin-biopsies of False Killer Whales and undertake genetic analysis to define the population in northern Australia. Hopefully this work will lead to appropriate research and management for these regular ocean-going visitors to our NT shores.

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## Notes on the form and habitat of nests of the Northern Shrike-tit

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### Introduction

The Northern Shrike-tit *Falcunculus frontatus whitei* is currently considered one of three subspecies of the Crested Shrike-tit (Christidis & Boles 2008). It is patchily distributed in the Top End of the Northern Territory (NT) and the Kimberley Region of Western Australia (WA), but there are relatively few records for the subspecies and it is listed as 'Vulnerable' nationally under the *Environment Protection and Biodiversity Conservation Act*, and in the Northern Territory under the *Territory Parks and Wildlife Conservation Act*. In WA, it is listed under Schedule 1 – "Fauna that is rare or is likely to become extinct". Robinson and Woinarski (1992) found 21 records from 16 localities for the species in the NT and seven from the Kimberley prior to the date of their publication. The NT Fauna Atlas (a database held by the NT Department of Natural Resources, Environment, The Arts and Sport (NRETAS)) contains 28 records for the subspecies, from about 22 sites in the NT (to July 2007). Two of these records are of nesting shrike-tits, both from the Borroloola region almost a century ago from collections by H.G. Barnard in January 1914 (Barnard 1914; White 1914). Other nests have been seen by bird-watchers both in the NT (S. Keates, pers. comm.) and the Kimberley (G. Swann, pers. comm.), but there is no published description. Here we report on the features of nests of Northern Shrike-tits found in the Maranboy area, approximately equidistant between Katherine and Mataranka, near where the subspecies was previously recorded by Holmes and Noske (1990).

### Methods

Northern Shrike-tits were typically located after hearing their calls. In some cases this was aided by broadcasting the call (Plowright 2007) to elicit calls or attract birds closer to the observer. Birds were then followed to record foraging, tree use and ranging behaviours, and in some cases the bird led the observer to a nest. Observations were aided by the use of binoculars. In one case, an abandoned nest was found by chance during a visual search for shrike-tits. More intensive observations of birds at the nest (for periods of between 1 h and 24 h) were made at three nests using a spotting scope (Kowa; x25), by an observer in a chair about 25 m from the base of the nest tree.

The height above the ground of most nests and or nest trees was calculated using trigonometry – either measuring the angle from observer up to the nest (clinometer

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$\pm 1^\circ$ ) and the distance of the observer from the base of the tree (or point directly below the nest; tape measure  $\pm 0.1$  m), or using a stick held in front of the observer to transpose the height of the tree to a length on the ground, at right angles to the line from observer to the tree, that was measured with a tape measure ( $\pm 0.1$  m). The height of a nest that was collected was calculated by measuring the length of a weighted piece of cord dropped from the nest to the ground (tape measure  $\pm 0.1$  m).

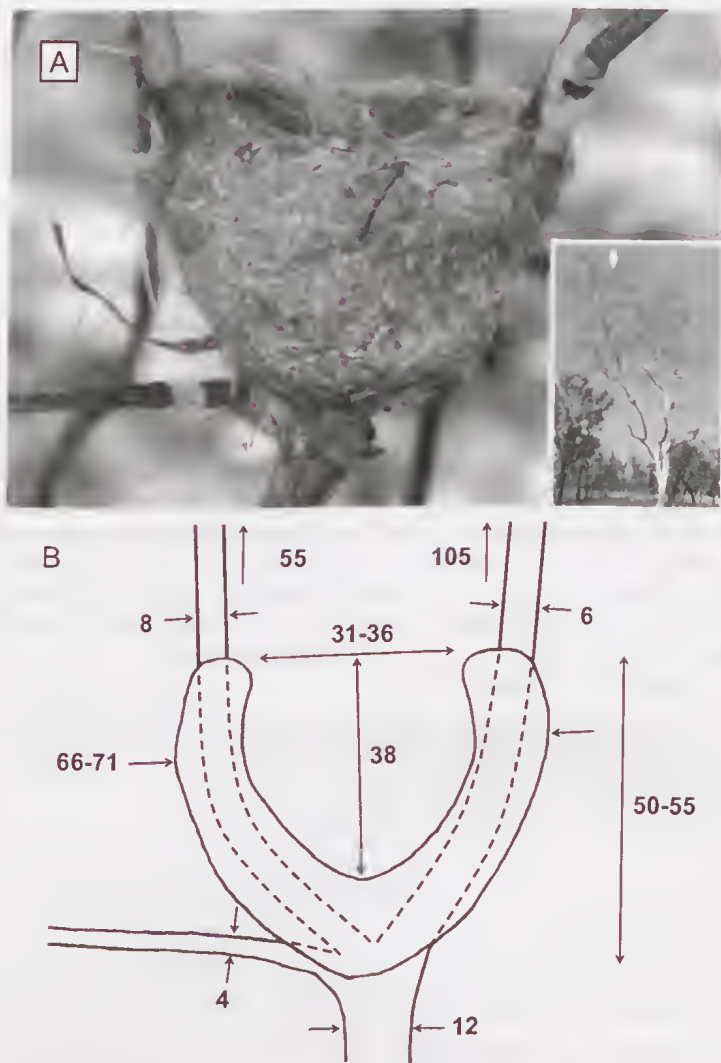
## Observations

In a search for shrike-tits in the Maranboy area in July 2007, one bird was seen and followed for about 30 minutes, but no breeding was apparent. We returned to the area in October 2007 and located a bird, and subsequently a nest, approximately 200 m (and on the opposite side of a bitumen road) from our sighting in July. Another nest, apparently unused, was found in a large tree approximately 120 m away. At this time another pair of Northern Shrike-tits was located 2.2 km away and was observed mating; the female bird was observed collecting what we believe was nesting material – fibrous bark material from subterminal branches of a box eucalypt tree. We subsequently found a nest in the vicinity of this pair in early December 2007. In October 2008 we found an occupied nest 40 m from the first 2007 nest (presumed to be the same pair) and, 460 m away in an adjacent territory, another pair was constructing a nest. One month later (November 2008), the former nest was abandoned and another was being constructed 220 m away; the pair in the adjacent territory was still constructing its nest.

In all six cases the nests were in eucalypt trees (*Eucalyptus*, *Corymbia*) and located in some of the top-most branches, within 10-15 cm of the edge of the crown (see inset Figure 1a). Details of the trees in each case are given in Table 1.

The abandoned nest found in October 2007 (A2, Table 1) was collected and has been lodged with the Museum and Art Gallery Northern Territory (NTMT3512). The nest is cup-shaped and constructed of fibrous bark and grass held together, particularly on the outside, by spider-web (Figure 1). The bark fibres and grass are densely matted, giving the nest a golden colour, and the walls incorporate two or three living branchlets which support the nest. The branchlets immediately above the nest had been snapped off within 10-15 cm of the top of the nest. During construction of another nest the male was seen using its beak to remove branchlets below the level of the nest so that leaves and twigs did not project over the nest bowl. The nest cup (34 mm diameter, 38 mm deep; Figure 1b) was big enough for one adult bird to sit in with eggs/chicks below.

The habitat around these nests was open woodland dominated by round-leaved bloodwood *Corymbia latifolia*, Darwin box *Eucalyptus tectifica*, large-leaved cabbage gum *C. grandifolia* and Cooktown ironwood *Erythrophloeum chlorostachys*, with a canopy height of 14-16 m (Figure 2). There were also scattered trees of weeping box *Eucalyptus*



**Figure 1.** Nest of a Northern Shrike-tit *Falcunculus frontatus whitei* from the Katherine Region of the Northern Territory: A. habitus (inset depicts nest tree *Corymbia grandifolia* with arrow showing location of nest, at the very top of the canopy); B. diagrammatic cross-section showing various dimensions (in millimetres), or ranges of measurements; numbers at the top show lengths (in millimetres) of two protruding branchlets. Photos and measurements were taken from an abandoned nest (MAGNT; NTMT3512).



*patellaris*, Darwin stringybark *Eucalyptus tetrodonta*, rusty bloodwood *C. umbonata* and *Acacia pallidifolia*. These were the only species in the immediate area that reached more than 2 m height. The undergrowth was very sparse with the ground covered in some areas by a variety of grasses (e.g. *Sorghum*, *Chrysopogon*, *Heteropogon*, *Aristida*) with leaf-litter predominating, though most of the area had been burnt earlier in the year (F. Piercc, pers. comm.). Termite mounds with a height to about 1 m were scattered across the area.

**Table 1.** Details of trees in which nests of Northern Shrike-tits *Falcunculus frontatus whitei* were found. Nests were seen in three territories (A, B & C). Nest no. refers to the order in which nests were found and described in text. DBH is the diameter-at-breast-height.

Territory code & nest no.	Date of observation	Tree species	Height (m)	DBH (cm)	Notes
A1	Oct. 2007	<i>Eucalyptus tectifica</i>	16.0	31	incubating
A2	Oct. 2007	<i>Corymbia grandifolia</i>	15.7	52	abandoned
C3	Dec. 2007	<i>Corymbia latifolia</i>	14.0	37	nestlings failed
A4	Oct. 2008	<i>E. tectifica</i>	13.7	27	incubating
	Nov. 2008				abandoned
B5	Oct. 2008	<i>E. tectifica</i>	13.4	27	constructing
	Nov. 2008				constructing
A6	Nov. 2008	<i>C. grandifolia</i>	15.9	29	constructing

In October 2007, the majority of *E. tectifica* trees had largely (if not solely) new foliage (including the tree with the active nest); many individuals of *C. grandifolia* also had new leaves or leaf buds and most carried very abundant flower buds. Hence the nests and attendant birds were very exposed. By December, most trees had some leaves on them but were not in full leaf. In October 2008, trees in this woodland generally had more foliage than was apparent the previous year.

Observations at the first nest (A1) during all daylight hours on 17 and 25 October 2007 found one or other of the nesting pair sitting on the nest at all times, except when chasing off intruders; hence, we presume that at this time the birds were incubating eggs. Ten days later, on 4 November, there was still an adult at the nest at all times (N. McCrie, pers. comm.), but on 20 November the nest was abandoned and adults were feeding a fledgling in a tree about 100 m from the nest-site. The other active nest (C3) was watched for several hours on 3 and 4 December 2007 and the pair appeared to be feeding chicks, though chicks were not seen or counted.

Nest construction was observed briefly at nest B5 in October 2008. The nest was well-formed when first found, probably more than 80% complete. During just over

two hours of observations, both the female and the male of the pair were seen in and around the nest, both calling frequently, but the female appeared to have the dominant role in nest construction. She was seen bringing fibrous material and bark to the nest, as well as tufts of white fluff – presumed to be spider-web or similar. One time she brought a tightly-woven cocoon to the nest and picked at it to unravel the thread and lay it into the nest. The male was seen collecting bark from the fine branches of a Darwin box tree in November 2008, and rolling and plucking it to produce fibres. He also did a small amount of construction.



**Figure 2.** Habitat around the nest of Northern Shrike-tits *Falcunculus frontatus whitei* in the Katherine Region of the Northern Territory, October 2007.

Frequency of calling was much greater in the months when nests were observed (October – December) than in July when no calls were heard from more than 50 minutes of observations (H. McGregor & S. Ward, pers. obs.), or one brief call in response to playback from several hours of searching interspersed with playbacks (F. Pierce, pers. comm.). We found playback using the recordings in Plowright (2007) of the Northern Shrike-tit very useful in locating birds in October to December and in March.

## Discussion

Clearly, data from more than three pairs at one locality are needed to define the variability in nest form and habitat that occurs in a species. The nests described here are similar in form to nests reported for shrike-tits near Borroloola, NT (White 1914), and in southern and eastern Australia (Higgins & Peter 2002), but are a little smaller. In comparison to the dimensions collated in Table 1 of Higgins and Peter (2002), the internal dimensions measured from our Northern Shrike-tit nest are at the lower limit of the range, or smaller, and the external dimensions are smaller than those measured previously. The position of the nest in the tree, high in the top-most branches, agrees with that reported elsewhere (Barnard 1914; White 1914; Higgins & Peter 2002). Richard Noske (pers. comm.) observed a female shrike-tit completing a nest in the Maningrida area of western Arnhem Land, c. 300 km north of our study site, in October 2008 (at the same time as we found nest numbers A4 and B5 in this study). The nest was c. 15 cm from the top of a paperbark (*Melaleuca viridiflora*) which was only 6 m high, and not in a eucalypt. The female was seen adding new material to the nest three times during a period of c. 10 minutes, while the very vocal male watched and called from as close as 2 m away.

The pairs of Northern Shrike-tits that made the nests described in this paper were actively nesting, or preparing to nest, in October and December in both 2007 and 2008, and R. Noske (pers. comm.; see above) also witnessed nest building in the Maningrida area during October. Barnard (1914) collected eggs from two nests near Borroloola in January 1914 (White 1914). In one case a chick was just hatching at the time of collection (Barnard 1914). In the Kimberley, Hill (1911) suspected birds to be nesting in early October, but could not locate the nest. There is a nest record for late November and an anomalous one for March (Birds Australia nest record scheme and Storr 1980, cited in Higgins & Peter 2002). It is apparent from these records that nesting of Northern Shrike-tits is concentrated in the build-up (October – December), which coincides with greatest insect activity (M.F. Braby pers. comm.), consistent with its breeding season in south-eastern Australia (Noske 2003), and may continue through the wet season to March. However, in view of the lack of breeding records beyond January in other parts of Australia (Higgins & Peter 2002; Noske 2003), and the dearth of calls during January in the Maningrida region (R. Noske, pers. obs.), late wet season breeding seems unlikely. The first pair described in this note (A1) was also seen mating in December, whilst still feeding a fledgling. Subsequent observations in January and March detected no re-nesting by the pair. Subsequent observations of the pair at nest C3 suggest that their nesting attempt failed: no fledgling was observed and there was no re-nesting attempt that season. It remains to be determined how many clutches are typically raised by a pair each year, and to what extent breeding occurs at other times of year. The evidence for multibroodedness in this species is weak and is confounded by its unusually long period of parental care (Noske 2003).

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Our observations all came from a relatively small area of eucalypt woodland south of Katherine. Most recent reports for the subspecies in the NT have come from the Katherine region (including this area; Fauna Atlas NRETAS), probably because the area is relatively accessible and is known in birding circles as a place to search for the subspecies (e.g. McCrie & Watson 2003). Much still remains to be known about the distribution and habitat preferences and requirements of shrike-tits in northern Australia. However, we hope that this brief note provides an impetus for other reports and descriptions of the nesting behaviour of this poorly known subspecies.

## Acknowledgements

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